Refrigerators Given Cold Shoulder:
Strategies to Improve Sustainable Refrigerator Management in Manitoba

By

Scott Nicol

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Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements
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Abstract

Refrigerators contain significant amounts of ozone-depleting substances (ODS), which must be recovered prior to disposal to prevent ozone depletion and climate change. Currently, municipal governments are burdened with appliance management – utilizing practices that encourage recovery of highly valuable resources but neglect recycling less valuable and safely disposing of hazardous components. More progressive strategies have emerged, however, incorporating product lifecycle analysis through end-of-life (EOL) manufacturer involvement and technologies that minimize pollution and increase component recovery.

This thesis examined EOL refrigerator management in Manitoba to recommend best practices and sustainable frameworks for management. Objectives included: 1) identifying critical issues in EOL refrigerator management and current waste management policy; 2) identifying gaps in Manitoba's refrigerator management policies, practice and procedure; 3) determining best management frameworks for sustainable management; and 4) recommending feasible management structures for implementation in Manitoba. To achieve these objectives, a number of activities were conducted including a literature review, site tours (Manitoba, UK), consultations with Manitoba Stakeholders, roundtable discussions and distribution of a refrigerator management survey and electronic questionnaires.

Manitoba's management system is unsustainable. The largest concern is that most of the ODS in refrigerators is allowed to be released, as regulations requiring its capture are limited to the cooling circuit only and not CFCs in the insulating foam. The insulating foam typically contains two-thirds of the CFCs in refrigerators. Municipalities

in Manitoba do not consider safe disposal of these foams, which results in the release of CFCs during the recycling process. Another unsustainable factor is that plastics and other components are not recycled but sent to landfill. Lack of waste management legislation for refrigerators has created over 200 individual municipal management strategies – each with their own criteria for disposal. Residents and municipalities lack proper education and pay as you throw disposal fees has resulted in improper disposals. Appliance resale of old inefficient refrigerators, which are twice the energy consumers of Energy Star models, result in large energy bills to the consumer of several hundred dollars per year. Operating one 20 year-old refrigerator has the carbon dioxide equivalent of running two automobiles for one year.

A study tour of refrigerator recycling facilities in the UK and a survey of North American appliance recycling programs provided examples of best management practices (BMPs) from regulatory and voluntary perspectives. Regulations on refrigerator disposal were found to be most effective, as the scope encompasses all units for recycling; targets and standards can be set; most advanced treatment technologies can be utilized; and producers can help with waste management and redesign of sustainable products.

To be proactive, refrigerators with high ozone depleting or global warming potential should be discouraged from use and sale and replaced by hydrocarbon technology, possibly through eco-rebate incentives. The most effective strategy for Manitoba would be to regulate EOL management through extended producer responsibility (EPR), replacing municipal management approaches with a single strategy, managed and financed by industry producers. Eventually, Manitoba's product stewardship framework must begin to include the principles of EPR for greater sustainability and to help drive design changes for increased refrigerator recyclability and lessen their environmental impact. In the absence of political will in Manitoba to implement regulations, a voluntary initiative can provide some level of environmental benefit focusing on reducing greenhouse gas (GHG) emissions and electrical demand by having a second fridge buy-back.

Acknowledgements

As I begin to reflect on this amazing journey I have taken over the past two years, filled with long days, sleepless nights, and lots of hard work, I feel a sense of accomplishment knowing now that a refrigerator is much more complex than keeping things cold. As one of the more unique undertakings at the NRI, perhaps the first of its kind, there are a number of individuals I would like to thank for imparting their knowledge, guidance, and support on developing this project.

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Acronyms

ABS	Acrylonitrile Butadiene Styrene
AHAM	Association of Home Appliance Manufacturers
ARCA	Appliance Recycling Centres of America
ARCI	Appliance Recyclers of Canada Inc.
ARF	Advanced Recycling Fee
BAT	Best Available Technology
BMP	Best Management Practice
CAMA	Canadian Appliance Manufacturers Association
CEPA	*Canadian Environmental Protection Act*
CFC	Chlorofluorocarbon
CREEDAC	Canadian Residential Energy End-use Data and Analysis Centre
CUFCA	Canadian Urethane Foam Contractors Association
DfE	Design for Environment
EU	European Union
EPR	Extended Producer Responsibility
GHG	Green House Gas
GWP	Global Warming Potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HDPE	High Density Polyethylene
HFC	Hydrofluorocarbon
HIPS	High Impact Polystyrene
HRAI	Heating, Refrigeration, and Air Conditioning Institute
IFO	Industry Funding Organization
IIR	International Institute of Refrigeration
ISO	International Standards Organization
ISWA	International Solid Waste Association
kWh	Kilowatt Hour
MOPIA	*Manitoba Ozone Protection Industry Association*
MR 103/94	[Manitoba] *Ozone Depleting Substances and Other Halocarbons Regulation 103/94*
ODS	Ozone Depleting Substance
ODP	Ozone Depleting Potential
OLPP	Ozone Layer Protection Program
PE	Polyethylene
PPP	Polluter Pays Principle
PUR	Polyurethane
PVC	Polyvinyl Chloride
RMC	Refrigerant Management Canada
TEAP	Technical and Economic Assessment Panel
TFDT	Task Force on Destruction Technologies
WEEE	Waste Electrical and Electronic Equipment
WML	Waste Management License

WRAP	*Waste Reduction and Prevention Act*
WRAPP	Waste Reduction and Pollution Prevention [Fund]
WTS	Waste Transfer Station
UN	United Nations
UEC	Unit Energy Consumption
US EPA	United States Environmental Protection Agency

1.1 Background

Refrigerators, along with other white goods (large domestic appliances) are not typical household wastes and cannot be easily disposed of along with the rest of the weekly refuse – because of their bulky nature and hazardous components, particularly their ozone depleting substances (ODS), within. The term "white good" originated within early department stores describing the porcelain finish applied to the appliance by the manufacturer—giving the unit its outer white appearance (Potts and Baker 1998). Over the years, the definition has expanded to encompass all major domestic appliances including those containing an ODS. This project, which focuses on refrigerator and chest freezer management, can also be broadly applicable to other ODS containing white goods such as dehumidifiers, air conditioners, water coolers, and heat pumps. ODS not only deplete the ozone but are potent greenhouse gases.

Refrigerator recycling programs can encompass a number of activities including ODS recovery, hazardous material removal, collection and transportation, and recycling and resource recovery. Other key aspects include energy conservation, climate change, regulations, and secondary use/product refurbishment.

1.1.1 Importance of Studying Refrigerator Management

There are a number of reasons why it is important to study the management of domestic appliances at the EOL stage. These reasons stem from both resource recovery and environmental perspectives.

1.1.1.1 Resource Recovery Perspective

Nearly 100% of all domestic appliances are recyclable. Recycling is very cost-effective for these products as refrigerators are made from a number of highly recyclable/reusable materials such as steel, copper, aluminium, glass, and plastics. Refrigerators, which are 75% steel by weight, contain at least 25% recycled content and upwards of 100% for internal mechanisms. High scrap steel value, $295 per tone on the American Metal Market (November 2007), has helped propel appliance-recycling rates to over 90% in North America – up from 84.9 in 2004. The benefits of recycling steel alone are enormous as it saves 2,500 pounds of raw ore, 1,400 pounds of coal and 120 pounds of limestone, while reducing air and water pollution by a combined 81%. In Canada, more steel is recycled than any other metal at an overall rate of 65%, which saves enough energy to power nearly 3 million homes (Crawford 2005, SRI 2006, SWRC 2007, Lindenbaum 2007, SRI n.d).

1.1.1.2 Environmental Perspective

From an environmental perspective, it is important to recognize that refrigerant from domestic appliances poses a significant risk to both human and environmental health – in the form of skin cancer, cataracts, decreased crop yields, and climate change.

Originally, domestic refrigeration utilized ammonia and sulfur dioxide as refrigerants, which were highly toxic and unstable compounds causing many fatal accidents. A conscience effort was made by industry to find safer replacements. Chlorofluorocarbons (CFCs) were created as a highly stable and safe (non-flammable and non-toxic) refrigerant. At the time, little was known about the destructive properties of

CFCs until a series of scientific discoveries proved otherwise. Dr. James Lovelock was the first to discover CFCs in the atmosphere, which sparked further research on the effects of chlorine in the air. The negative effect of anthropogenic sources of chlorine was never fully understood until Rowland and Molina's ozone depletion theory in their 1974 *Nature* article *Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom-Catalyzed Destruction of Ozone*. They explained when CFCs are released they migrate up into the stratosphere where ultra violet radiation effectively splits them apart, creating a free radical of chlorine. This chlorine then attracts a single oxygen atom (split from an ozone atom during the natural ozone creation/destruction process), thus destroying the natural ozone cycle. The atmospheric lifetime of chlorine from CFCs ranges between 50-250 years and one CFC molecule can destroy upwards of 100,000 or more ozone molecules in its lifetime. Although many were highly skeptical of the uncertainty surrounding the science at the time, their ozone depletion theory was proven when a team of British scientists led by Joe Farman, discovered a severely depleted layer of ozone over Antarctica, which is commonly known as the 'ozone hole.'

The ozone layer is one of the most important aspects protecting life on planet earth. Ozone is dispersed some 40-km thick throughout the stratosphere, however, when compressed its thickness is comparable to that of a penny, such that if it was compressed to zero degrees Celsius at one atmospheric pressure it would be approximately three millimeters thick (ICS 1997). It is the only barrier protecting the planet from the harmful effects of UV A + B radiation from the sun. Without the ozone layer, millions of new cases of cataracts and melanoma skin cancer would be reported on a worldwide basis each year.

The international community, facilitated by the United Nations (UN) adopted the *Vienna Convention for the Protection of the Ozone Layer* (1986). This Convention made it compulsory that participants take the most appropriate actions towards safeguarding the stratospheric ozone layer (Benedict 1991). The result of the *Vienna Convention* was the *Montreal Protocol on Substances that deplete the Ozone Layer* (1987), which "establish[d] a schedule to reduce the global consumption of five CFCs and three halons" (Standing Committee on Environment 1990:19). The original Protocol instructed developed nations to stabilize or freeze CFC consumption (which is defined as production + imports – exports) at 1986 levels one full year following the implementation of the protocol starting January 1, 1989 (CFCs) and January 1, 1992 (halons). The original version of the protocol calls for consumption of CFCs to be reduced by 20% as of 1993-94 and by 50% in 1998-99. A number of amendments have been made to the protocol, which addresses accelerated phase out of new ODS (Standing Committee on Environment 1990).

Canada developed an Ozone Layer Protection Program (OLPP), which involves co-operation between federal and provincial levels of government (Environment Canada 1997). Federal responsibilities focus on issues considered to be of national interest and include ensuring the terms of the Montreal Protocol are implemented within Canada. Two regulations have been developed under the *Canadian Environmental Protection Act* (CEPA), which include the *Ozone-depleting Substances Regulations* and *Federal Halocarbons Regulations.* The ODS regulations are Canada's official commitment to the Montreal Protocol and provide control measures on importing, exporting, manufacturing, consuming, and selling ODS. Changes to the ODS Regulations can "be made as required to reflect changes in reduction and phase-out schedules adopted by the Parties to the Montreal Protocol" (Environment Canada 1997:13). CEPA also contains the *Environmental Code of Practice for Elimination of Fluorocarbon Emissions from Refrigeration and Air Conditioning Systems*, which serves as a guidebook for best practices on emissions reductions and in the absence of regulation, can be upheld in a court of law (Environment Canada 1997, K. Warren, July 19, 2007). Provinces regulate emissions, mandate recovery and recycling of ODS, and administers environmental awareness training and certification for the refrigeration and air conditioning sectors (Environment Canada 1997).

1.2. Problem Statement

Manitoba's current EOL refrigerator management system is, at best, a patchwork of nearly 200 different municipal management systems lacking a unified approach for post consumer management, which often leads to improper management such as incorrect disposal or vented refrigerant.

1.3 Purpose

The purpose of this project was to study the system of EOL refrigerator management in Manitoba, identifying gaps in policy, practice, and procedure to be able to correct shortcomings through recommending frameworks for sustainable management practices. The overall purpose is to ensure sustainable refrigerator management within Manitoba.

1.4 Objectives

The overall objective of this project was to recommend suitable management frameworks and related components for sustainable EOL management of refrigerators in Manitoba. This was accomplished by identifying gaps in policy, practice and procedure within Manitoba's current management system and researching where these areas can be improved through the transfer and incorporation of BMPs learned from other jurisdictions.

The outcome of this study was satisfied by the following four objectives:

1. Identified the critical issues for refrigerator management (resource and environmental management perspectives) and current waste management policy.
2. Reviewed Manitoba's current refrigerator management system to identify where gaps occur in policy, practice and procedures.
3. Determined best management frameworks (including best practices, policies and procedures) for sustainable refrigerator management.
4. Recommended most feasible management structures for sustainable refrigerator management implementation in Manitoba.

1.5 Methods

The following methods, which are discussed in greater detail in Chapter 3: Methods, were employed to fulfill this projects objectives:

1. Municipal landfill site tours
2. Scrap metal recyclers site tours
3. Used appliance dealer site tours

4. Roundtable discussions
5. Manitoba stakeholder interviews
6. UK refrigerator recycling plants site tours
7. Electronic questionnaires
8. Literature review
9. Refrigerator Management Survey

1.6 Project Scope

The scope of this project encompasses North America and Europe, however, it focuses on Manitoba for its recommendations and UK and Manitoba for its tours of facilities. Studies within Manitoba included visiting landfills in selected municipalities to ascertain current management practices. The UK study area included site visits of two refrigerator-recycling plants where all aspects of the EOL phase (collection, transportation, ODS recovery [refrigerant and foam], and material separation and recovery for reuse and recycling) were examined. In North America, participants from various jurisdictions throughout the US and Canada were contacted for participation in a survey examining voluntary management systems.

1.7 My Interest in the Subject Area

I was presented with a unique opportunity to work with the *Manitoba Ozone Protection Industry Association* (MOPIA) in developing a municipal guidebook of suggested practices for white goods management. However, to fully understand the immense scope and nature of this subject area, it was necessary to go beyond MOPIA's limited resources and conduct research on a broader scale. Also, this research builds upon previous experience taking into account my BA in Environmental Studies from the University of Winnipeg and my work with the Waste Reduction and Pollution Prevention (WRAPP) Fund at Manitoba Conservation (responsible for coordinating the Fund).

1.8 Definitions

- Best Management Practices: policies, practices, procedures, and structures that through experience and research have proven to reliably lead to a desired result (Whatis.com 2005).
- White Goods: the term "white good" originated within early department stores describing the porcelain finish applied to the appliance by the manufacturer – giving the unit its outer white appearance (Potts and Baker 1998).
- Ozone Depleting Substance: are stable chemicals comprised of chlorine, fluorine, and bromine, which degrade under ultra-violet light in the stratosphere and are responsible for destroying ozone. ODS include, but are not limited to CFCs, hydrochlorofluorocarbons (HCFCs), halons, carbon tetrachloride, methyl chloroform, and methyl bromide (US EPA 2007).
- Greenhouse Gases (GHG): these are gases that are transparent to incoming short wave solar radiation, but are opaque to outgoing long wave radiation – effectively trapping heat in the earth's atmosphere and creating a greenhouse effect. These gases mimic the glass found in a greenhouse. The two major greenhouse gases are water vapour and carbon dioxide, with other gases including methane, ozone,

nitrous oxide, CFCs, HCFCs, and hydrofluorocarbons (HFCs) (Visionlearning 2006).

- Halocarbon: chemical compounds linking one or more carbon atoms to one or more halogen atoms including chlorine, fluorine, bromine, or iodine and encompass all anthropogenic ozone depleting and global warming substances (Wikipedia 2007c).
- Refrigerant: a chemical compound used to transfer heat – absorbs heat by evaporation and expels heat through condensation (HELMS 2007).
- Refurbishment: upgrades a product to current standards, both aesthetically and mechanically, which may include maintenance and repair work (Wikipedia 2006b).
- Product Stewardship: is a multi-stakeholder approach to end-of-life waste management that includes participation from all actors along the product chain including the producer, manufacturer, importer, distributor, retailer, consumer, reseller, and recycler (NWPSC 2001 *in* Toffel 2002)
- Extended Producer Responsibility: is an environmental policy approach in which the producer is responsible for, both physically and/or financially, a product beyond the post consumer stage of the product lifecycle (OEDC 2001).
- Design for Environment (DfE): which "supports product developers in reducing, already at the development phase of a products life cycle, the environmental impacts through enhancing the product design…[which] includes resource consumption, both in material and energy terms and pollution prevention" (Dantes 2006)

1.9 Thesis Organization

This thesis will be organized into six chapters – after the Introduction (Chapter One) is the Literature Review (Chapter Two) where I focus on examining key elements of refrigerator management and waste management policy. I follow this by Methods (Chapter Three). The findings are divided into two chapters beginning with Refrigerator Management: Manitoba (Chapter Four) and Regulatory and Voluntary Approaches for EOL Refrigerator Management (Chapter Five). Finally, a discussion and recommendations conclude this thesis in Conclusions and Recommendations for Improving Manitoba's Refrigerator Management Policies, Practices and Procedures (Chapter Six).

2.1 Introduction

This literature review is divided into five sections namely: 1) environmental impacts; 2) recycling techniques and resource recovery; 3) refurbishment; 4) waste management policy and 5) case study. Its main focus is to identify relevant waste management policy and establish the critical (base) components for a white goods management strategy.

2.2 Environmental Impacts of Refrigerators

Refrigerators have many impacts on the environment as they can contain ODS and toxic materials (mercury, PCBs and mineral oils), as well as, consuming large amounts of energy. These impacts are discussed in the following sub-sections.

2.2.1 Domestic Refrigeration: Ozone Depletion and Global Warming

The refrigerant in refrigerators used today contributes to ozone depletion and climate change. In this section different refrigerants will be discussed and their impacts on the environment, as well as, options to recover both refrigerant and halocarbons from their insulating foam.

2.2.2 Refrigerant Leaks

One of the biggest concerns regarding domestic appliances is refrigerants and their ability to negatively effect the environment in terms of ozone depletion and climate change. These appliances contain approximately 150g as refrigerant of the following halocarbons: CFCs, HCFCs, or HFCs (Environment Canada 2003). During their useful life, these compounds can escape from the equipment if there is a leak.

Leaks are generally the result of holes that have developed in the hermetic system, which seals in the refrigerant and lubricating oils. These holes can arise from mechanical damage or from a defect that can show up in the later years of appliance use. In some circumstances, holes can be present before the unit leaves the factory and can take up to six years to appear. In most cases, the unit can continue to function even while leaking refrigerant. Aside from using special leak detection equipment the only way to detect a leak is if there is pungent oily smell, where refrigerant is being replaced with normal air while the compressor is still running. The smell will be from the mineral oil, which is not developed to operate in a high heat, oxygen rich environment (Fridge Doctor.com 2003).

2.2.3 Ozone Depleting and Global Warming Potentials (ODP/GWP)

ODP is the ratio of impact a particular ODS has on ozone relative to the impact of the reference gas CFC-11 [ODP = 1] (US EPA 2007). This allows different ODS to be compared using a single universal unit, which is displayed as CFC-11 equivalents – such that not all ODS are uniform in terms of their ODP (i.e. CFC-12 = 1 and HCFC 141b = 0.1) (Scottish Executive: Environment 2003).

Halocarbons have some of the highest GWPs out of all sources of GHGs. GWPs look to assess the possible impacts that a certain gas may have. It is therefore defined as "the cumulative radiative forcing—both direct and indirect effect—integrated over a period of time from the emission of a unit mass of gas relative to some reference gas" (USEPA 2002:8). The chosen gas of reference is carbon dioxide (CO_2), with a GWP of one. Out of all the ozone depleting substances, CFC-12 is the most potent greenhouse gas with a GWP of 10,600 and CFC-11 at 4,600 over a 100-year period.

HFCs, which do not deplete ozone, are powerful greenhouse gases and have been identified within the six main basket gases of the *Kyoto Protocol*. They are primarily used as replacements for ODS refrigerants and are also emitted as a byproduct of the HCFC-22 manufacturing process. The primary refrigerant HFC-134a has a 100-year GWP of 1,300 (US EPA 2002).

2.2.4 Global Warming and Domestic Refrigeration

Carbon dioxide is emitted as a result of generating electricity necessary to power appliances – especially if the power is generated through burning coal. In total, twenty percent of global warming can be attributed to refrigeration, with 20% of that from the release of halocarbons and 80% from electricity consumption (IIR n.d). It is predicted that by the year 2050, without responsible use, HFCs could possibly account for approximately 2% of all GHG releases (AHAM/EPA 2005). The combination of all major domestic appliances in a home can be directly linked to the release of nearly 2,500-kg of GHGs each year (Calgary Think Climate Change 2003). To put the climate impact of a single EOL CFC or HFC/HCFC refrigerator in perspective, assuming the loss of 150 g of refrigerant and more than 125 g of blowing agent (average 25% immediate loss of 500 g), one refrigerator of either type has a carbon dioxide equivalent as calculated in Table 2.1. This is the equivalent of releasing 2.165 metric tons of carbon dioxide.

Table 2.1: Climate Impact of One CFC or HFC/HCFC Refrigerator

Halocarbon	Charge (Metric Tons)	GWP 100 Years	CO_2 Equivalent (Metric Tons)
CFC-11	0.000125	4,600	0.575
CFC-12	0.00015	10,600	1.59
Total			**2.165**
HCFC-141b	0.000125	580	0.0725
HFC-134a	0.00015	1,300	0.195
Total			**0.2675**

(Modified from: Thomas, Tennant, and Rolls 2000).

2.3 Refrigerant Recovery

The first step in any refrigerator management program is the recovery of refrigerant, which is performed by a trained certified refrigeration technician. The literature has identified two best-practice methods for the recovery of halocarbons via the active or adsorption ("Blue Bottle") recovery methods.

2.3.1 Active Recovery Method

The active recovery method involves the use of a compressor equipped with a filter-drier and condenser, which extracts the refrigerant. The recovery unit is first attached to the appliance though the use of hoses. When the refrigerant is in its gaseous state, it is transferred over to the recovery unit by the compressor, which feeds the gas into the condenser—transforming it into a liquid. From there, the refrigerant is sent from the recovery unit to a pressurized cylinder for storage. This system is certified for the recovery of CFC-12, HCFC-22, and HFC-134a, with a recovery efficiency that varies anywhere from 80 to 96% (Environment Canada 2004).

2.3.2 Adsorption Method

The Blue Bottle method uses a cylinder containing a Halozite matrix to adsorb the refrigerant from the appliance. The system is connected to the appliance via hoses and the gaseous refrigerant is transferred through diffusion to the recovery unit as the refrigerant air-stream passes through the cylinder. A vacuum pump is used to create suction to further remove all refrigerants from the unit. When the unit's Halozite matrix is completely saturated, the cylinder is returned to the manufacturer (Halozone), which is a centralized reclamation plant where the refrigerants are desorbed for reuse or destruction. Following desorption, the Halozite matrix is recharged and the cylinder is ready for reuse.

Halozone ensures "virtually 100% recovery of ODS from non-condensable streams emitted when purging chillers, evacuating equipment or leak testing, and from low volume refrigerant applications such as the servicing and decommissioning of…residential refrigerators" (OCETA 2006:1-2). Blue Bottle allows recovery of ODS from the appliance without any changes in chemical composition of the refrigerant. The major drawback to this system is the cost related to transporting the recovered refrigerant to the reclamation facility, which can be far away from the location of desorption (Environment Canada 2004, OCETA 2006).

2.4 CFCs as Auxiliary Blowing Agents in Insulating Foams

Manufacturing a refrigerator requires the use of approximately 400g to 600g of halocarbon blowing agent (often five times the amount found in the cooling circuit), which is used to propel and insulate plastic foams. Most refrigerators utilize rigid polyurethane (PUR) foam because this particular type of insulation has a high R-value (which resists heat flows) in comparison to other types of insulation. CFC-11 was a common auxiliary-blowing agent that once the foam settled, rigid closed cells formed effectively trapping in the CFC-11 gas. This gas has twice the R-value of ambient air, which provides greater resistance to heat flow and thus a higher R-value. On average, polyurethane foam is made up of approximately 10-15% CFC-11. The downside to using polyurethane foam is that during the manufacturing and drying process nearly 40% of the CFC-11 that was used, escapes into the atmosphere. Once the foam is dry and has hardened, a process called thermal drift occurs, where the R-Value of the foam declines as CFC-11 is slowly escaping and replaced by ambient air. Stabilization of the foam usually occurs two years following manufacture (EREC 2004, Willis 2006). The Task Force on Foam EOL Issues, part of the Technological and Economic Assessment Panel (TEAP) to the *Montreal Protocol*, predicts that at any given time there is a total of one billion refrigerators in use representing an estimated 500,000 tonnes of banked CFC-11 or other halocarbons (UNEP 2005).

2.5 ODS Destruction

The Task Force on Destruction Technologies [TFDT] (also part of TEAP) recommend the thermal oxidation (high heat) or plasma destruction process for ODS elimination (UNEP 2003). To achieve thermal oxidization, incinerators are set to a temperature of 900°C or higher, which is the point at which organic compounds can be destroyed. Specially designed kilns (for stable organic compounds) are set at a higher temperature around 1200°C, which permits a 99.9999% destruction rate. High temperature is needed because refrigerants have low heat values, which can only be achieved by using such fuels as propane and natural gas (Earth Tech 2003). The TFDT approved the following six techniques for thermal oxidation: liquid injection incineration, reactor cracking, gaseous/fume oxidation, rotary kiln incineration, cement kilns, and municipal solid waste incinerators (for ODS foams) (UNEP 2003).

Currently, nine facilities in the world are UN sanctioned for the destruction of ODS, including the Swan Hills Treatment Centre in Canada (Earth Tech 2003). The cost to dispose of refrigerants will "vary depending on the quantity, the level of contamination by oils and other refrigerants, and the distance to the disposal facility" (Environment Canada 2003:13).

2.6 Hazardous Materials

An equally important aspect of managing refrigerators and chest freezers is the identification, removal, handling, and proper destruction of hazardous materials such as mercury, PCB's, and refrigerant oils. The following is a list of hazardous materials contained in refrigerators including a profile of their human/environmental health risk and the policies and regulation in place to reduce their emissions.

2.6.1 Mercury Switches

Elemental mercury occurs naturally in the environment (soil, water, and the atmosphere). It is an extremely hazardous and toxic metal, that when allowed to evaporate, can contaminate a large area of the surrounding environment. Mercury can become released into the environment through a number of ways including evaporation, incineration, or landfill disposal—such that the majority of mercury currently contained within the natural environment originates from some type of human-made product or source. Once in the atmosphere, mercury can be dispersed through wind currents and is deposited onto land through precipitation and once ingested bioaccumulates in fatty tissue of animals. Exposure to mercury results in mercury poisoning. The effects of mercury poisoning can be severe attacking the brain, liver, and kidneys leading to paranoia (AMRC 2002, California EPA 2004, Pollick 2006).

Liquid mercury's "unique properties have made [it] useful in a variety of consumer electronic devices and products" (California EPA 2004:2). The predominant source of mercury in white goods is found in mercury switches. They operate by encapsulating a small amount of elemental mercury within a sealed glass tube with two unconnected electrodes at each end. When the mercury is located at one end of the tube the electrodes remain unconnected and will not permit the flow of electricity. If the switch is tilted the mercury will accumulate between the electrodes and allow electricity to freely pass through creating a completed circuit. Once the tube is moved to the original position, the circuit is broken and the flow of electricity is halted (Pollick 2006). Tilt switches are used to turn appliances (or their lights) on and off (California EPA 2004:3). Mercury switches tend to be small in size but can come in a number of shapes including "bullet-shaped capsules and pellets, elongated bulbs and probes, and thin capillary tubes…[and] can be made of steel, plastic, or glass" (California EPA 2004:3).

Since mercury is such a versatile substance, permitting electrical flow under certain climatic conditions (i.e. temperature and moisture), it has been used for decades within domestic appliances, specifically chest freezers. Many chest freezers manufactured prior to the year 2000 can contain a mercury switch within the light socket of the internal lid light. In this case, the mercury switch acts as a sensor to detect lid movement, which activates the internal light. There are two general types of switches found in chest freezers and include light socket switches with hard plastic or rubber casing or a less common glass ampoule switch. These types of switches are usually found "inline of the wiring of the freezers light and [are] located inside the cover, in the insulation" (AMRC 2002:7). Removal may require cutting a section out of the plastic lid liner and insulation, which surrounds the switch itself. Typically, a chest freezer light switch will contain approximately 1.0 grams (1-2 drops) of mercury.

Sales estimates of chest freezers in the United States (1990s) suggests 190,000 units were sold to consumers with a mercury switch, which is up from 106,000 units in the 1980's (AMRC 2002, California EPA 2004, ARIC 2005). As of January 1, 2000, chest freezers are no longer manufactured with mercury switches, with the on/off function of lighting controlled by a manual light switch (a push button or plunger type of device) (AMRC 2002, California EPA 2004).

2.6.2 Polychlorinated Biphenyl's (PCBs) and Capacitors

There are likely only a small number of major home appliances manufactured prior to 1979 still currently in use, which contain a capacitor made with PCBs. PCBs are an oily fluid consisting of up to ten chlorine atoms attached to a biphenyl, giving the substance certain "thermal and dielectric properties, which made them an ideal electrolytic substance" (Wikipedia 2006a:1).

Smaller PCB capacitors were commonly found in windowsill air conditioners and microwave ovens and were identified as running or oil filled capacitors. These capacitors were designed to help electrical motors operate at a higher efficiency because PCB oil allowed heat to dissipate within the capacitor as the motor was running, thus minimizing electrical voltage fluctuations. A world-wide ban was placed on PCBs in 1979 because of the extreme human and environmental risks associated with their use. They are considered a Persistent Organic Pollutant (POP) and have entered into the environment through use and disposal. PCBs bioaccumulate in the fatty tissue of humans and animals and are highly soluble in fats, in addition to, being a known carcinogen (liver and biliary tract).

US regulation and mandatory replacement and destruction of capacitors containing more than three pounds of PCB's was ordered in the 1980's, however, appliances were spared because their capacitors contained such a small quantity of PCBs and were allowed to be used throughout the appliances lifecycle. Most other major household appliances (refrigerators and chest freezers) did not contain running PCB capacitors. However, they did utilize a starting or dry capacitor without a PCB substance. As a note, the U.S. Environmental Protection Agency (EPA) writes that "based on current average life expectancies, most of the pre-1978 household appliances that may contain PCB capacitors have already passed through the municipal solid waste stream" (Connecticut DEP 2005, Wikipedia 2006a, ARIC n.d:1).

2.6.3 Mineral Lubricating Oils

Lubricating refrigerant oils (usually mineral and housed in the compressor) pose certain human health risks if improperly handled. Numerous studies have proven that untreated mineral oils are known carcinogens, and can affect the skin, scrotum, gastrointestinal system, and bladder (Report on Carcinogens n.d). In addition, up to 20% of the dissolved ODS can remain in the oil.

The U.S. EPA suggests that when removing oils, the appliance should be pressurized to a maximum of 5psig such that "this reduced pressure will greatly reduce refrigerant emissions while permitting a slight positive pressure to force the oil from the compressor" (US EPA 2006:1). To remove refrigerant oil from small hermetic compressors without an oil drain outlet, it is necessary to remove the compressor from the unit in order to drain the fluid. The most appropriate place for oil removal is at the suction line of the compressor, such that 95% of the oil can be recovered at this point (MOPIA 1994).

2.7 Energy Consumption

A 10-15 year old refrigerator will consume 1,800-2,000 kilowatt hours (kWh) of electricity, more than double the amount of an energy efficient appliance manufactured today. The average life span for a chest freezer is approximately 21 years and a refrigerator is 17. If an appliance is in excess of this average, it is most likely consuming more energy and costing more money to operate than it should (Hydro One Networks n.d).

People who are accustomed to keeping an older second refrigerator do not realize how much money it actually costs them to run it. A 17-ft^3 refrigerator manufactured in 1984 will consume nearly 177% more electricity (1,457 kWh/year) than a similar sized 2002 energy efficient model (526 kWh/year) (Calgary Think Climate Change 2003). The Canadian Residential Energy End-use Data and Analysis Centre [CREEDAC] (1996) conducted an extensive study to approximate the average unit energy consumption (UEC) of major domestic appliances within Canada for the 1993 model year, which included both refrigerators and freezers. The results showed that the UECs were 1,320-kWh/year (refrigerators) and 790 kWh/year (freezers). Refrigerators of concern are those models manufactured between the years of 1972 and 1993, as in 1994 the United States introduced minimum energy efficiency standards for refrigerators.

2.7.1 Deterioration of Energy Efficiency: Loss of Auxiliary Blowing Agent

The rate at which a refrigerator or freezer consumes energy will vary greatly over that appliances life span – never at a consistent rate. It has been found that one of the major determinants affecting energy efficiency the greatest is due to the loss of auxiliary blowing agents in the insulation. Due to this loss, the R-value of the foam degrades over the products life span, such that it will negatively effect the way in which it consumes energy (i.e. the greater the degradation of the blowing agent the more energy will be needed to power that product). A mathematical model was developed by R.W. Johnson of the Whirlpool Corporation for determining the decrease in energy consumption over a period of time as part of a Total Environmental Warming Impact Analysis (TEWI). The calculation is as follows:

$\blacklozenge E = r[(20-n)/20]^x$

where:
r = initial ageing rate for the blowing agent in question
n = year
x = a factor chosen to match the expected final energy consumption, considering the data from Wilks et al (1999). (Johnson 2000 *in* Horie 2004:23)

Since the switch from CFC-11 to alternative blowing agents, it is evident that polyurethane blown with HFC 245fa has the best ageing characteristics under Johnson's calculation compared to other agents such as HCFC-141b, HFC-134a, and cyclopentane. Within the model, the ageing rates of the three previous agents declined at a quicker rate than with HFC-245fa. Johnson (2000) writes that the choice of blowing agent will also influence the thermal conductivity of the foam. The energy consumption and efficiency of a refrigerator will ultimately depend on three things: 1) the design of the product, 2) the thickness of the walls, and 3) the properties of the insulating foam – which depends on the choice of blowing agent. Therefore, the "choice of blowing agent can affect the maximum efficiency that is attainable for a product design over many years" (Johnson 2000 *in* Horie 2004:24).

2.7.2 Insulating Agents and their Effect on Energy Consumption and Global Warming – using Life Cycle Analysis.

In a study by the American Plastic's Council, they were able to measure the difference in energy consumption and greenhouse gas emissions between two refrigerators—one using polyurethane foam and the other glass fibre insulation. The use of "lifecycle analysis takes into account the energy used and the greenhouse gases emitted during the production of each insulating material and the energy and greenhouse gases consumed and produced in the operation of the respectively insulated refrigerators and freezers" (Hentges and Edgecombe n.d:2). The energy required in manufacturing refrigerator and freezers is not included in this study because they are the same for both products and will not influence the final results.

Life cycle analysis is used to gauge the environmental impacts that are associated with a product over its life span and is usually measured from the cradle to the grave. Lifecycle analysis, as identified by the International Organization for Standardization (ISO) looks to recognise these impacts by "1) identifying and quantifying energy and materials used and wastes released to the environment, 2) assessing the impact of the energy and materials used and released to the environment, and 3) identifying and evaluating opportunities for environmental improvements" (ISO 1998 *in* Horie 2004:5).

The study assumed that the appliances used electricity that was drawn from a national power grid (in this instance the U.S. power supply), which is representative of all the different methods of power generation – hydroelectric, nuclear, coal, petroleum, and natural gas. Carbon dioxide produced from the combustion of coal, petroleum, and natural gas, which is the principal greenhouse gas. In addition, the manufacture of polyurethane foam requires HCFC-141b as a blowing agent and is considered a greenhouse gas. The GWP of this agent was taken into consideration through releases during the manufacturing process, foam ageing, and through disposal. The average life span of the refrigerator was assessed at 19 years and the "energy content of the insulation's and the energy to manufacture them has been taken from various life cycle inventories for the products" (Hentges and Edgecombe n.d:3).

The results showed that polyurethane foam consumed 39% less total energy throughout the production and use phase of its lifecycle compared to that of the refrigerator using glass fibre insulation. The most significant use of energy was during the use phase of the product and the energy needed to manufacture the insulating material is quite insignificant. The energy saved by using polyurethane foam was expressed in terms of fossil fuels: natural gas-16,354 ft^3, petroleum-0.66 barrels of oil, and coal-4,953 pounds.

Emissions from the manufacture of polyurethane foam contribute to five percent of global warming, whereas, only 0.06% come from the manufacture of glass fibre insulation. It is assumed that "93% of the difference in greenhouse gas emissions from the manufacture of the two insulating products is due to the assumption that all of the HCFC-141b is lost over the lifetime of the refrigerator" (i.e. foam is shredded and disposed) (Hentges and Edgecombe n.d:3).

Although the HCFCs have a significant GWP by themselves, it is not as stark as the emissions that are released as a result of operating the unit over its life span—such that there is a direct correlation between carbon dioxide and energy consumption over the products useful life. Polyurethane insulation helps to reduce electrically generated CO_2 emissions by up to 35% over glass fibre. It was assumed that if 106 million refrigerators were outfitted with polyurethane foam instead of glass fibre, it would reduce CO_2 emissions by 34.9 millions tones and save nearly 50 million kilowatt hours (Hentges and Edgecombe n.d, Johnson and Bowman, 2003).

2.8 Waste Management and Resource Recovery from Refrigerators

According to Environment Canada (2004) refrigerators make up at least 70% of all appliances recycled in municipal recycling programs on a yearly basis. They have identified that at least 73% of the total weight of an appliance consists of recoverable resources such as steel, aluminium, and copper. If a refrigerator weighs 100 kg, 73 kg of that is recyclable scrap metals (Environment Canada 2003).

2.8.1 Refrigerator Recycling Techniques

Stoop and Lambert (1998) provide five frameworks for recycling discarded refrigerators:

Open shredding: refrigerators mixed with other metals and processed in an open-air car shredder. CFC-12 and compressor oil, if not recovered, escapes into the environment and partial release of CFC-11 in PUR foam. Component parts are recovered using magnets (ferrous), eddy current separation (non-ferrous) and remaining shredder light fraction (plastics, glass, foams) is sent to landfill (remainder of CFC-11 escapes over time).

Recycling with CFC-12 and oil recovery: CFC-12/oil mixture is captured using active recovery method, separated, and either reused or destroyed. Plastic bins, metal/glass shelves, and compressor are recovered for reuse and any hazardous components (mercury switches) are removed. Refrigerator is manually disassembled into panels – ferrous metal is recycled, plastics and foams are disposed.

Recycling with PUR treatment: refrigerator is disassembled into component parts and the cooling system drained. PUR is manually separated from metals and pneumatically fed through a matrix with small holes (Koller mill). Chilling and condensation capture CFCs and remaining fraction is disposed.

Closed shredding: refrigerator is shredded within a contained environment, minimizing CFC-11 loss to the environment.

Incineration: CFC-12/oil mixture recovered and compressor shredded. Remaining carcass manually dismantled and incinerated with domestic waste – destroying CFCs, PUR and plastics. Molten metals can be recaptured and released heat is used to generate electricity.

In the US, appliance disposal and recycling techniques can be characterised by the following:

- Open shredding of 90% of appliances without blowing agent recovery – reusable resources recovered, remaining fractions disposed;
- 7.5% of appliances crushed whole and disposed;
- 1.5% of appliances shredded with blowing agent recovery or destruction; and
- 1% of appliances abandoned or reused (UNEP 2005).

2.8.2 Resource Recovery Efficiency

Kondo *et al* (2001) experimented on the resource recovery efficiency of various refrigerator-recycling techniques for mono-material component recovery (i.e. pure fractions). Three different recycling methods were used including open shredding, manual disassembly, and a combination of open shredding and disassembly. Open air shredding achieved about a 75% per weight mono-material recovery efficiency with high recovery of ferrous and PUR fractions. Complete manual disassembly was not as effective with a recovery rate of only 30% per weight and in some cases recovered components showed signs of physical damage or were degraded by chemical use. The most effective strategy was a combination of both methods, which achieved an excess of 80% per weight mono-material component recovery

2.8.3 Plastics Recovery

There has been a large expansion in recent years in the amount of plastics used within major household appliances and that the traditional model of managing these materials, typically sent to the landfill at the EOL stage, is unsustainable. Once a refrigerator carcass has been manually processed and the ferrous and non-ferrous fractions recovered what remains is the plastic fraction. Composition of plastics used to manufacture refrigerators will depend upon the producer, however, will generally include several of the following polymers: high impact polystyrene (HIPS), acrylonitrile butadiene styrene (ABS), polyvinyl chloride (PVC), or polyethylene (PE) (Pasco 2006). Integrated resource management is now required to develop alternative materials, which utilize post consumer plastics. It is predicted during 2007, refrigerator disposal alone will yield nearly 203 million pounds of ABS and HIPS plastic, which allows for an excellent opportunity to recover and reuse these relatively pure streams of plastic. The composition of plastics will determine the actual value of the recovered plastic and its value over time will depend on the types of plastics used by the producer during the manufacturing process (Zolotor 2007).

Refrigerator recycling programs must ensure that procedures are developed for processing plastics from units manufactured 15-20 years ago, in addition to, being able to adapt to future changes in plastic compositions. Techniques for the physical separation of various plastic polymers used in refrigerator manufacturing have already been developed and include density separation, triboelectrification froth floatation, and the Argonne process. The latter, which is the only commercial technique for separating HIPS and ABS (a difficult process because of similar chemical properties), utilizes a 50% solution of acetic acid as a separation medium. Hydrocyclone system have been tested using water and calcium chloride solutions, but are not as effective as the Argonne process (requires small particles) however, is useful in treating finely shredded plastics that would otherwise be discarded (Pascoe 2006). Another experiment tested the properties of older refrigerator plastics for "notched izod impact strength, tensile yield strength, elongation at break, multiaxial impact strength, and melt viscosity" (Zolotor 2007). The results showed that the recovered plastics averaged below typical refrigeration grade plastics used at the time, but were within range of the ABS and HIPS grades that are commercially sold today (Zolotor 2007).

2.8.4 Blowing Agent Emissions

Most emissions of ODS blowing agents from white goods occur at the EOL stage using the open shredder recycling method where 100g can immediately be lost (however, may range from 8-40% with an average of 25% depending upon how fine the PUR is shredded). A Danish experiment at the Technical University of Denmark evaluated the off-gassing characteristics of CFC-11 from shredded refrigerator foams. Small cubes were cut out of a discarded refrigerator's insulating foam and each placed in its own glass container. The cubes themselves were monitored for CFC content (distribution within the cube), as well as, the space (air) immediately above them. The final "analysis indicated that the headspace over the foam cubes contained increasing amounts of CFC over time up until about 300-500 h[ours], at which time a pseudoequilibrium was reached" (Willis 2006:1). According to these results, the off-gassing rate of CFC emissions was approximately 100-10,000 times the normal rate for which off-gassing naturally occurs in normal, intact polyurethane foam. When the insulation is placed in an open air landfill, nearly 10% of the gas escapes within the first week or two, with 50% of the remaining gas released within the next ten plus years, depending upon the size of the foam fragment (Appliance Design 2001, UNEP 2005, Willis 2006).

TEAP predicts that the majority of remaining CFC-11 emissions from the appliance sector will occur from PUR in landfills from 2015 onwards. Models predict there will be approximately 250,000 tones of blowing agent in landfills, which will gradually be released over time. Although some studies of landfill soils have shown that complete degradation of CFC-11 by microbial action can be achieved (UNEP 2005).

Globally, over 30% of appliances containing CFC-11 have been taken out of commission by 2003 and this is expected to increase by 2010 based on an average refrigerator lifecycle of 15 years. TEAP suggests that if ODS emissions reductions in the appliance sector are to be realized, now is the time to implement measures to capture EOL CFC-11 – with another 150,000 tones to be recover from the refurbished appliance market after 2015 (UNEP 2005). To minimize emissions, TEAP has suggested the manual disassembly process for appliances, which should only result in the emission of 3g of blowing agent. Recovered foams, in the form of sandwich boards, can then be placed in airtight bags and delivered for direct incineration destruction (UNEP 2005).

2.8.5 Recycling of PUR

Zevenhoven (2004) notes two options for PUR reuse and include mechanical (regrinding, adhesive pressing, and compression moulding) and chemical treatment. Regrinding refers to finely powdered PUR that is added to the production of new PUR or is processed into pellets for oil spill binding. Adhesive pressing takes scrap PUR particles and coats them with a resin to form into products like mats, automotive sound insulation, and carpet underlay. Compression moulding takes PUR particles and fuses them together at high temperatures and pressures without the use of a resin creating a variety of products like automotive door and dashboard panels and field-turf athletic playing surfaces (mixed with recycled rubber chips). Chemical processing is used to reduce the volume of PUR by converting into a two-phased liquid (using heat or steam). The liquefied fractions can then be used in compression or reaction injection moulding.

2.9 Refurbishment

Currently, there are two differing schools of thought pertaining to appliance refurbishment – originating from both North America and Europe. North American approaches appliance refurbishment from an energy efficiency standpoint stating older appliances are a drain on electrical resource systems and therefore discourage refurbishment. However, Europeans argue that refurbishment can be a source of cheap appliances to lower income families and is even promoted through regulation and by some major recycling firms.

Refrigerators run on almost a constant basis and are considered the largest consumer of electrical energy within most households. Refrigerators can consume up to

40% of a household's electrical energy (in combination with other major appliances) and nearly 11% of the total energy (natural gas and electricity) per year (Calgary Think Climate Change 2003, Clean Air Partnership n.d). On a global scale, the International Institute of Refrigeration (IIR n.d) reports that domestic refrigeration accounts for nearly 15% of total global electricity consumption. Typically, energy consumption by a domestic refrigerator is measured by looking at how much energy is needed to power the unit for a 24 hour period while maintaining a consistent temperature via consumer activated controls (Canadian Standards Association 2000). However, to have a better understanding why older refrigerators are discouraged from refurbishment—a review of the principles of refrigeration should be discussed.

2.9.1 Principles of Refrigeration

Domestic refrigeration works similar to that of human perspiration, such that when a liquid evaporates it carries heat away from its source. All refrigerators will contain a liquid refrigerant, which boil at low temperatures. Cooling occurs when the refrigerant evaporates inside the coils within the refrigerator and a fan blows air across the coils and into the perspective compartments. Once this has occurred, the refrigerant (in gaseous form) is transported to a condenser coil, where it is compressed and allowed to cool off – releasing any excess heat into the surrounding environment. As the refrigerant (in liquid form) is transferred to the evaporator, pressure is released and the cycle is allowed to continue (Ecomall: A Place to Save the Earth n.d). It is necessary to describe this cycle because many of the inefficiencies of domestic refrigeration are a direct result.

2.9.1.1 Refrigerator Inefficiencies

Energy consumption for refrigerators ultimately began to increase in the 1970's when manufacturers introduced several energy intensive design changes. The most significant, was shifting the motor from a top mounted position to the bottom of the unit. This meant that instead of releasing the heat from the condensing stage above the unit, it was now being expelled and radiated back up into the main food compartment. This also coincided with manufacturers using far less insulation as a means of increasing the volume within the refrigerator, without actually increasing the size of the overall unit.

The switch from fibreglass to PUR allowed for a reduction in thickness of the exterior metal frame and interior plastic shell, but reduced the total amount of insulation that could be housed within the unit (90mm of glass insulation was replaced by 40mm of PUR) (Hentges & Edgecombe n.d). This lack of insulation was directly related to condensation build-up on the exterior, so manufacturers integrated heaters into the design to remove the water build-up on the surface and added heaters to the freezer compartment to control frost build-up. This is primarily why North American refrigerators of the 1970's consumed 2,000 kWh/year, more then double those in Japan. Consumption was also four times greater than 20 years previous in the 1950's when units used only 500 kWh/year with a top mounted motor (Ecomall: A Place to Save the Earth).

Extra conveniences also add to electrical consumption such that side-by-side door configuration adds 12% more energy use than traditional top mounted freezer models, indoor water and ice dispensers 10%, and in-freezer ice makers 14-20% (Forbes 2001).

2.9.2 North America

Refurbishment usually entails extending the useful life of an appliance regardless if it is in working condition or not. In Canada, a highly competitive used appliance market exists often with several players vying for relatively small profit margins. Resellers can acquire old or used appliances from numerous sources including apartment buildings, rental properties, scrap metal peddlers, and major retailers. The type and style of units refurbished will generally depend upon consumer demand, which is often for white and stainless steel units encompassing a range in ages sometimes as old as 20 years (CAMA 2005).

Since older appliances are energy intensive, refurbishment in North America is highly discouraged – with utility companies organizing bounty style programs targeting the removal of older refrigerators from the electrical grid and recycling them – preventing their reuse or resale. Over a one year period in 2001, a refrigerator recycling program in Southern California processed 72,000 old fridge's saving 435.1 million kWh of electricity (Southern California Edison n.d).

2.9.3 Europe: Refurbishment in the UK

The European approach, with specific reference to the UK, towards appliance refurbishment is quite different than the prevailing North American paradigm. Currently, residents in the UK discard nearly 350,000 tonnes of white goods on an annual basis, which translates into an average of 8 million units.

Within the UK, there "remains a real potential for the refurbishment and repair of such equipment, [such that these] activities might spread the use of these appliances to those unable to afford them" (DTI 1999:2). The Department of Trade and Industry (DTI) characterize refurbishment as a 'social responsibility,' such that it should be in the nature for charitable organizations to collect and take back old appliances for refurbishment (DTI 1999). Even Sims Group UK Limited, a refrigerator recycler in the UK, promotes refurbishment as a suitable option. They "partner with social and community groups in order that refurbishment of fridge's, where possible can be undertaken, so that they can be re-used as high quality, low-cost appliances" (Sims: Recycling Solutions 2004:1).

The condition of older white goods when they are received by the refurbisher, will generally dictate how much work must be put into the unit to bring it up to operating and safety standards under the Electrical Equipment (Safety) Regulations 1994. All refurbishers who supply secondary equipment must ensure that their products are in compliance with the safety requirements under this Regulation. In a survey of refurbishers, virtually all responded that they diligently test their appliances to the Portable Appliance Testing (PAT) standards to ensure the electrical device is safe to operate. If the appliance is fairly new, possibly just off-lease or returned under warranty, then little needs to be done to bring it up to standards (DTI 1999).

Typically, the refurbisher will fix and complete all the work to ensure that the unit can be sold on the secondary market for a reduced price compared to the purchase price of that same product, brand new. These secondary white goods are often referred to as 'B-class sales.' Refrigerators are among the most common white goods refurbished. People who purchase these appliances tend to be the ones who do not want to purchase or cannot afford the price of a new unit and typically include low-income families, students, and new homeowners. In some instances, refurbishers may restrict who has access to the purchase of these secondary units, such that potential customers provide proof of low-income status. In other cases, grants may be provided for the purchase of secondary units for groups of extremely underprivileged peoples (DTI 1999).

A number of organizations have been developed across Europe for the refurbishment of appliances as a means of providing training and work experience to unemployed peoples. CREATE (Community Recycling Enterprise and Training for Employment) was developed in 1995 to provide positive work experience to reintegrate unemployed people into the workplace. CREATE operates by collecting unwanted white goods for refurbishment and sale to the public. They collect units from individual households and retailers and can typically handle 200-300 units per week. They usually only deal with certain brands, whose spare parts are easily accessible and appropriately priced. They have their own transportation system for collection and delivery of refurbished goods to the customer's home, however, they do not exclusively deal with low income families but a wide range of customers including students and first time home owners (DTI 1999). Overall, the "make of the appliance concerned, and the ease of obtaining and replacing parts will influence a decision concerning whether or not to refurbish" (DTI 1999:4).

2.10 Waste Management Policy

Walls (2003) states that the ultimate goal of environmental policy is to maximize social welfare. In economics, pollution and waste disposal are considered externalities (negative effects of the production and consumption processes), but when these externalities are internalized social welfare is increased. To maximize the overall social welfare, environmental policies need to obtain the socially optimal level of waste or pollution where the benefits outweigh the costs of pollution/waste reduction. Policies need to obtain an efficient level of environmental externality in the most cost-effective fashion. The Polluter Pays Principle (PPP), which most traditional environmental policies have been based on over the past 30 years, meets the requirement of both efficiency and cost effectiveness by making those who pollute bare the cost of ensuring a healthy environment (OECD 2001).

2.10.1 Policy Implementation

There are two different approaches for implementing environmental policies: 1) mandatory regulations or 2) fully voluntary measures. A mandatory approach utilizes legal requirements (such as regulations) for prescribing policies, whereas voluntary approaches can consist of a wide variety of arrangements from co-operation between industry organizations or agreements reached between industry and government authorities. There are debates, however, over which approach is superior as industry officials state voluntary initiatives are most cost effective by achieving environmental goals far cheaper than regulations would. Sheehan and Spiegelman (2005) also state regulations tend to create monopolistic enterprises, which suppress market competition. On the other hand, critics argue voluntary programs lack the credibility of regulations, do not have clear objectives and goals, and fail to achieve stated targets (Gibson & Lynes 1998 *in* Quinn 2003). Overall, McKerlie, Knight and Thorpe (2006) state voluntary initiatives, more often than not, prove to be less effective than regulatory standards.

2.10.2 Policy Tools

Whether mandatory regulations or voluntary initiatives, a number of policy tools exist to aid the policy implementation process. Advanced recycling fees (ARF) are a tax on the sale of new products to the consumer and are used for establishing recycling infrastructure. Landfill bans prohibit the disposal of particular items and have been effective for recovering highly recyclable products like refrigerators. Pay as you throw is a fee administered on end-users wishing to dispose of a particular product. Other policy tools include product take back, recycled content standards, recycling rate targets, raw material charges, waste collection charges, eco-rebates, and eco-labelling (Walls 2003; 2006).

2.10.3 Product and Producer Responsibility Policies

Environmental policies have predominantly focused on end-of-pipe solutions for pollution prevention and waste disposal. Realistically, the implications of these policies (such as the PPP) are not being felt throughout the entire product chain such that policies applied at the level of externality, rarely, if ever, achieve their objective (OECD 2001).

Policy development is now emphasising 'life cycle analysis,' which analyses cradle-to-grave impacts of products produced and extends waste management responsibilities for one or more stakeholders along the product chain, effectively exploiting all avenues for waste reduction (i.e. raw materials, component reuse, recycling, etc.) and pollution prevention. Product and producer responsibility policies have emerged as potential solutions to minimize environmental impacts of products and as workable alternatives to the PPP (Nicol & Thompson 2007). This section introduces two policy frameworks, extended producer responsibility (EPR) and product stewardship.

2.10.3.1 Extended Producer Responsibility

By definition, EPR is an "environmental policy approach in which a producer's responsibility, physical and/or financial, for a product is extended to the post consumer stage of a products life cycle" (OECD 2001:18). Physical responsibility refers to the direct or indirect handling of the product at the end of its life span, whereas, financial responsibility is where the producer pays for most or all of the end-of-life costs (OECD 2001). The goal is to transfer the burden of product disposal away from the local government and taxpayer to the producer, where "the environmental costs of treatment and disposal could then be incorporated into the product" (OECD 2001:18).

Generally, the producer is in the best position to assume waste management responsibilities as they have the highest level of control over their product in terms of creative design and material selection. By internalizing the costs of waste management, producers can implement Design for Environment (DfE), where products are designed to accommodate a reduction in input materials, reduce toxicity levels, and incorporate older parts into newer models (Franklin 1997). Overall, EPR policies have three main characteristics: (1) a focus on EOL waste management to encourage environmental redesign, (2) physical/financial shift of responsibilities from municipalities/tax base to producer and (3) meeting explicit targets for waste reduction (Nicol & Thompson 2007).

One of the first EPR initiatives targeting the management of refrigerators and other electronic appliances was the Dutch *White and Brown Goods Decree* 1998.

Retailers and municipalities were mandated to take-back appliances from consumers and producers had to provide free collection, transportation, and recycling. Recovery and reuse targets were negotiated with industry and set at 75% for refrigerators with a $17 ARF. The recovery and reuse targets established in 1998 were far exceeded by 2000-2001, where the recycling rate for refrigerators reached 85.5%. Producers were only required to cover the costs of recycling and eventually the program was discontinued as other aspects such as collection and transportation became too costly. Based on its short timeframe, it is unknown if the program actually provided any incentive to producers to spur design changes. One Dutch official said he doubted if it did because the ARF paid by residents was uniform across all brands and did not consider different product sizes or designs. Sachs (2006) highlights a similar problem in Belgium with where an ARF of 20 Euros applied to refrigerators reflected only the costs of waste management and did not consider research and development – providing little incentive to producers for product redesign. Lambert and Stoop (2000) stress that when recycling complex products such as refrigerators, policies not providing feedback to the producers are destined to underachieve.

Looking specifically at the product redesign aspects of EPR (as applied to refrigerators), the President of the Frigidaire Company Hans Backman stated, "industry will now aggressively design products up front for environmental considerations, including design for disassembly and recyclability – environmental concern will become a product design specification" (Davis 1994 *in* Wilt 1997 *in* Davis *et al* 1997:4-1). Frigidaire's internal environmental policies strive for sustainability by designing their products to be completely recyclable. A pilot project entitled *Refrigerator Recyclability Assessment* was launched with the idea of creating a completely recyclable refrigerator.

The first step was to completely dismantle a refrigerator to determine the amount of time needed to disassemble a unit by a two-person crew. Using hand tools and a power saw, the team took 32 minutes to disassemble a unit, not including the insulated portions, which took more time and effort to take apart. Several findings were discovered including 1) not all plastics could be identified, 2) too many varieties of plastics were used, and 3) the insulating foam portion of the unit took too much time to disassemble.

Based on these findings, Frigidaire amalgamated numerous plastics used during the manufacturing process eliminating three separate clear plastics from different manufacturers. A decision was made to switch to polycarbonate, which achieved a similar look to the previous types of plastic and in the end "resulted in improved part quality, as well as, achieving a ten percent reduction in materials price due to purchasing a larger volume of material from one supplier opposed to three" (Wilt 1997:4-5). The number of parts needed to manufacture the door handles and trim were also reduced without compromising performance or look. Handle assemblies were now significantly more recyclable as they were reduced to 20 parts from 58.

A switch from a high-solids paint system to an organic powder system eliminated the emissions of 2.2 million pounds solvents while offering a better overall finish and better corrosive protection. They also instituted a Returnable Reusable Container Program (RRC), which reduces 80% of the packaging necessary for transport. Wooden pallets, paper, and cardboard were replaced with reusable polyethylene pallets and containers and saved 3 million dollars in the first year alone. As an effort to reduce the disposal of shredder fluff after recycling of appliances, Frigidaire began to mark all of its plastics according to its resin type. Making use of the ISO 1043 standard, all plastic parts are labeled and identified for future dismantling and recycling – which has now become an industry standard. Overall, Frigidaire "is working with its suppliers, processors and manufacturers, as well as with representatives of consumers, dismantlers, and shredders to assist in developing the most recyclable product" (Wilt 1997:4-6).

2.10.3.2 Product Stewardship

U.S. industry pressure has been a stumbling block towards EPR introduction in North America, which instead has promoted shared responsibility type programs – often refereed to as product stewardship. This is an environmental management strategy, which uses a multi-stakeholder approach to advocate participation from a number of actors along the product chain including producers, manufacturers, distributors, retailers, recyclers, and consumers. Responsibilities are assigned as follows: producers establish collection and recycling infrastructure, consumers pay levies and deliver products to collection depots, retailers help collect wastes, and governments establish standards (Nicol & Thompson 2007, NWPSC 2001 in Toffel 2002, Sheehan & Spiegelman 2005, Mckerlie, Knight, & Thorpe 2006).

Stewardship policies have been successful, to some degree, at increasing recycling rates, however, they have failed in a number of other areas. Producer involvement is limited, which fails to internalize the cost of waste management – providing no feedback regarding life cycle impacts. These policies fail to prevent waste, provide incentive for DfE, set targets, or phase out hazardous components (Sheehan & Spiegelman 2005, Mckerlie, Knight, & Thorpe 2006, Nicol & Thompson 2007).

2.10.4 Waste Management Policy within Canada: Manitoba and BC

Within Canada, provincial policies dictate responsibilities for management and collection of solid waste as it falls within the scope of local municipalities - who levy the cost of management through the municipal tax base, rather than incorporating this cost into product pricing. Waste management subsidies, combined with inefficient production processes, poor product design and over consumption, have helped to create a 'disposable society' within Canada (McKerlie, Knight, & Thorpe 2006, Sinclair & Quinn 2006).

Many waste and recycling policies have taken a regulated product stewardship approach, with over 30 federal and provincial programs operating mainly because the federal government does not presently have the authority under CEPA to mandate producers to take back a specified waste product. The policy strategy adopted by many provinces for implementing product stewardship is to enact a broadly focused, overarching statute such as a waste disposal act. This Act then grants the Environment Minister the power to designate materials, establish program requirements, create levies, and set performance standards and reporting requirements (Swanson 2003; McKerlie, Knight & Thorpe 2006).

In Manitoba, the *Waste Reduction and Prevention* (WRAP) Act was developed to prevent waste, after its generation, through recycling using the principles of sustainable development by adopting practices and programs focused on reducing and preventing waste. This Act establishes the regulatory framework for all WRAP activities within the province, which are primarily funded through WRAP levies (costs associated with manufacturing or distributing a designated product within the province). Industry funding organizations [IFOs] (independent non-governmental organizations made up of product stewards – those who must pay WRAP levies) are responsible for managing WRAP levies, which are used to fund a number of related activities including:

- Designated product management;
- Public education;
- Collection, transportation, storage, processing and disposal of designated wastes;
- Research and development; and
- Training for designated material management.

Manitoba Conservation: Pollution Prevention is responsible for implementing the Act and administering fines - $25,000 and/or one year prison term for individuals and $250,000 for corporations. Current regulations consist of *Used Oil, Oil Filter, and Containers Stewardship Regulation* and two Tire Stewardship regulations (original and interim). A Packaging and Printed-Paper Regulation has yet to be enacted (replacing the Multi-material Regulation) and Electronics and Household Hazardous Waste regulations are currently in development (Quinn 2003).

British Columbia's stewardship strategy does not include the shared approach but rather places responsibility of managing life cycle impacts of wastes with industry producers and consumers, which is referred to as 'full product stewardship'. This is perhaps the closest North American governments will come to implementing EPR as the principle of full product stewardship is to shift all management responsibilities for designated products to industry producers including financing, operating, education, collection, and responsible disposal. This strategy has produced tangible results such as providing incentive for DfE (soda containers evolving from glass, to thick walled plastic (with high-density polyethylene [HDPE] lower cap), to thinner, single stream plastic). Major soda producers in BC are also pledging to increase recycled content of single serve plastic containers (McKerlie, Knight & Thorpe 2006).

2.11 Case Study: UK's Response to Mandatory Refrigerator Treatment Regulations

The first wave of concern regarding the management of end-of-life refrigerators in the United Kingdom came via European Legislation No: 2037/2000 on Ozone Depleting Substances, which is a regulation that automatically becomes law in each member state (Hogarty n.d). The main components of the regulation came into force in October of 2001 and stated by January 2002, it was mandatory to remove all controlled ODS from domestic refrigeration equipment before it was scrapped or recycled. Prior to 2037/2000, UK legislation called only for CFC recovery from the cooling circuit and did not provide guidance on the removal and treatment of insulating foams. Small appliance repair outfits and independent contractors were primarily responsible for degassing appliances, as it is their 'duty of care' under the Environmental Protection Act to deliver recovered ODS to an authorized person for recycling or disposal. Despite this provision, most simply vented the gas into the atmosphere as they bore the costs for ODS destruction (£40.00 per 10kg container) (FOE Scotland 2001).

Prior to regulation, upwards of 3.5 million refrigerators were disposed of annually in the UK – averaging nearly 7,000 on a daily basis. For disposal, an elaborate retailer take-back scheme operated, which saw appliance suppliers retrieve old units, free of charge, when delivering new ones. Nearly half of all discarded appliances entered this system, with Local Authorities collecting the remainder (at £10-£15 per appliance). Used refrigerators were stored at retailer depots until purchased by small-business appliance refurbishers for continued use. Forty percent of used refrigerators from the UK were exported overseas (West Africa and Eastern Europe), with another 15% refurbished for the domestic market. The remaining units, those unfit for reuse, were degassed and recycled for their scrap metal using conventional open-air shredding (Clover, 2001, Holton 2002, Strömberg & Ringström 2004, Bate 2005, Hogarty n.d, Williams n.d).

In October 2001, Article 11 of 2037/2000 became law stipulating a ban on exports of ODS equipment to non-EU countries. This effectively crippled the retailer return scheme and since refrigerators were not permitted to leave the country, it bankrupted many of the small businesses relying on this trade. For the retailer, it was now uneconomical to collect and store units if the excess could not be sold, forcing them to suspend free take-back and shift the burden of waste collection to the local authorities, who had to store every appliance until a solution for treatment could be found. In Wales, as in the rest of the UK, local governments had to provide collection services for discarded refrigerators and could charge for those services, however, they could not charge for the disposal of that appliance. No specific waste fridge related policies were prevalent, therefor, local governments had to rely on overarching waste management policies (Florence and Price 2005).

The UK government expected all fridge's collected by local authorities to be stored prior to treatment and thus created 'Fridge Mountains,' 5-10 meter high piles of rusting steel carcasses strewn haphazardly over 50 acre sites across the country (estimated 1,500 refrigerators per acre). In order to store fridge's, local authorities had to obtain a Waste Management License, which added to fridge collection costs. Local media soon dubbed the situation a 'crisis,' which saw fires break out at several storage sites including Manchester (400m^2 area x 4m high) where air and run-off samples showed concentrations of styrene, toluene, benzene, and Faustian gas – a toxic byproduct of burning refrigerant. The demise of the return system, combined with confusion over storage requirements, led to an increase in 'fly tipping' – illegal dumping in areas like farmers fields (Clover 2001, Dooley 2002, Holton 2002, Stoker 2003, Florence and Price 2005, Hogarty n.d, Williams n.d)

Other areas of Europe, such as Germany, had nearly a dozen fully functioning refrigerator recycling plants in operation by 1993 – more than ten years in advance of 2037/2000. One such plant in Schleswig Holstein, operated by German waste firm RWE, collected and processed over 130,000 refrigerators each year from area residents and businesses. Logistically, the plant recovered CFCs and mechanically separated component parts for resale to industry partners. Reclaimed ODS was then sold back to chemical manufacturer Hoescht for reuse or destruction. Other member states such as Austria and Sweden also utilized these advanced recycling plants, with Italy, Spain and Denmark soon following suit (Pollack 2002). At the time, the UK's recycling infrastructure was not technically capable of fulfilling the requirements of the regulation. To help finance local collection and upgrade the processing infrastructure to regulatory standards, the UK's central government provided 40 million Pounds to help resolve the situation (Williams n.d).

A number of factors were to blame as to why fridge recycling was handled so poorly. There was a misunderstanding between the UK government and the EU over technical requirements regarding insulation foam treatment and local governments were not aware of the requirements of the regulation until three months prior to implementation. Furthermore, the Environment Agency failed to respond to several stakeholders (retail, waste management) regarding compliance and were unaware of the fridge export market. Overall, this situation highlights the lack of communication between all effected stakeholders during the policy development process – highlighting the lack of communication between the various levels of government (international, national, and local) (Williams n.d)

3.1 Research Study Method

A qualitative research design was employed, incorporating interviews, participant interaction, field observations, and document review (Creswell 1994). This approach was applied to examine current EOL refrigerator management practices within the Province of Manitoba and management frameworks in other national/international jurisdictions.

3.2 Objectives-Methods Link

Table 3.1 highlights how the objectives of this project were fulfilled by the methods as described below in Section 3.3 *Specific methods of my research design.*

Table 3.1: Objective-Methods Link

Objective	Method
1) Identify most critical aspects/components of refrigerator management and current waste management policy frameworks	• Literature and document review
2) Review Manitoba's current refrigerator management system to identify where gaps occur in policy, practice and procedure	• Literature review • Municipal landfill site tours • Scrap metal recyclers site tours • Used appliance dealer site tours • Manitoba stakeholder interviews • Electronic questionnaires • Roundtable discussions
3) Determine best practices, policies and procedures for sustainable refrigerator management (regulatory/voluntary)	• Literature Review • UK refrigerator recycling plants site tours • Electronic questionnaires • Refrigerator Management survey
4) Recommend most feasible management structures for sustainable refrigerator management implementation in Manitoba	• Literature review • Roundtable discussions

3.3 Specific Methods of this Research Design

This research design was selected to examine EOL refrigerator management practices within Manitoba to determine gaps in policy, practice and procedure, which could then be filled by management strategies and BMPs learned from other jurisdictions. The ultimate goal was to recommend management strategies to improve the sustainability of Manitoba's EOL refrigerator management system.

The methods that were used to accomplish this goal included visiting many EOL destinations for white goods and comparing the situation in North America (Manitoba) to that in Europe (UK). Field observation and interviews were undertaken in the following tours:

Municipal Landfill Site Tours: ten municipal landfills (see Table 3.2) across Manitoba were selected to provide good representation for site visits in order to gather visual information, discuss strategies, and identify regional trends towards managing refrigerators with municipal waste managers whose responsibility it was to consider these appliances. Municipal landfills were selected based on their proximity to other activities (i.e. MOPIA awareness sessions or NRI field trips). Each site was checked to see if stockpiled refrigerators were undamaged (i.e. no cut or broken refrigerant lines), had decommissioning labels (depending upon jurisdiction), and if they had their own separate storage area. Discussions with landfill attendants focused on disposal fees and the role of the resident and municipality.

Table 3.2: Municipal Landfills Toured and Geographical Region

Town and/or Municipality of Landfill	Geographic Region within Manitoba
Flin Flon (City)	North-west
Mystery Lake (RM)/Thompson (City)	North
Kelsey (RM)/The Pas (Town)	North-west
Winnipeg (City)	Central
Brandon (City)	West
Hanover (RM)/Steinbach (City)	South-east
Winkler (City)	South
Bifrost (RM)/Arborg (Town)	Interlake
Dunnottar (Village)	Interlake
Springfield (RM)	Central

Scrap Metal Recyclers Site Tours: two scrap metal recyclers, General Scrap [Winnipeg] and Manitoba Metals [Selkirk], were toured to identify key issues surrounding recycling of refrigerators in Manitoba. Units pending recycling at each site were checked to ensure they did not contain any refrigerant or hazardous components. The recycling process (open air automotive shredding) was then observed. Discussions with operators focused on their acceptance policies (with or without refrigerant), hazardous components, treatment (or lack of) of PUR foams, and end markets for recovered fractions.

Used Appliance Dealer Site Tours: two local used appliance shops were visited (one formally, another informally) to discuss issues pertaining to appliance refurbishment. Specifically, the visits were used to identify sources of appliances, resale volumes, target markets, and age of reconditioned appliances. A demonstration of the refrigerant recovery and charging process was provided during one visit, which was used to ensure compliance with Manitoba regulations.

Roundtable Discussions: two roundtable discussions were held to explore policy options for refrigerator management and the feasibility of treating PUR wastes. The first group examined how Manitoba's regulatory waste management framework (product stewardship) could be extended to cover refrigerators during a Product Stewardship Roundtable discussion. This meeting, which consisted of five participants (two committee members, primary advisor, and the researcher), occurred at MOPIA and was facilitated by the researcher (see Appendix E for the Roundtable agenda). One committee member, a policy analyst from Green Manitoba, helped guide the discussion on stewardship. The second group investigated options for EOL treatment of foams from refrigerators and other applications utilizing PUR. This meeting consisted of three participants, one committee member, the researcher, and the Executive Director of the Canadian Urethane Foam Contractors Association (CUFCA). The meeting also took place at MOPIA (see Appendix F for Roundtable agenda).

Manitoba Stakeholder Interviews: eighteen local Manitoba stakeholders involved in refrigerator management were interviewed either in person, by telephone or email. Stakeholders were chosen based on previous contact with the researcher at MOPIA or during the landfill site tours. Interviews lasted on average 10-30 minutes and data was recorded primarily into the researchers notebook. The purpose of these interviews was to answer questions or clarify concerns not covered during site visits. Stakeholders included appliance resellers, utility representatives, scrap metal recyclers, municipal officials, landfill operators, and provincial officials.

UK Refrigerator Recycling Site Tours: two UK refrigerator recyclers, M. Baker and Sims Metal, were selected to study the regulatory aspects (policy, practice, and procedures) of refrigerator management in Europe. The UK was chosen, over more environmentally focused/waste policy driven countries such as Germany (where fully automated refrigerator recycling has occurred for nearly fifteen years), because of similarities in its previous management style to that of Manitoba (i.e. improper disposal, vented refrigerant, etc.). Tours were used to investigate and examine all aspects of the management process from procedures and standards in the waste management license to a demonstration of BATs illustrating how refrigerators are recycled to prevent pollution.

Electronic Questionnaires: Questionnaires, see Appendices B-D, specifically pertaining to site tours in both Manitoba and the UK were developed to fill gaps within the field notes, which were not addressed during the site tours. Questions focused primarily on the recycling process (Manitoba) and elements of the pre *WEEE Directive* management structure in the UK (i.e. role of the resident and local authorities, refrigerant destruction, collection and transportation of refrigerators, etc).

Literature and Document Review: the literature review provided critical background information to orient the research and identified previous research findings – detailing structures in EOL refrigerator management and waste management policy.

Refrigerator Management Survey: the survey included ten participants (eight U.S. and two Canadian) from various North American jurisdictions (see Table 3.3) in order to identify BMPs utilized in voluntary programs. Specifically, looking for which types of appliances are accepted (primary/secondary), who recovers refrigerant and how, are PUR foams treated, and what types of incentives are given to encourage appliance recycling (among others).

Participants were selected based on criteria of utility/incentive driven appliance-recycling program (defined as a program where the utility provides an incentive to the customer to recycle their old inefficient unit) and were identified through Internet searches and by referee. All participants were contacted by phone and an electronic version of the survey was emailed to them. The survey was limited to ten final participants to prevent repetition in the data collected, as there are numerous such programs operating within North America. Seven written surveys were received back and three telephone interviews were conducted based on survey questions. The survey, available in Appendix A, is divided into 15 sections based on various aspects of appliance management and policy tools. The final version included a total of 38 questions (with two participants receiving an early version with 34 questions). Participants were not required to answer every question – only questions they were comfortable with answering or could provide information on.

Table 3.3: Refrigerator Management Survey Participants

Participant	Organization Type
Austin Energy (Texas)	Utility
Sacramento Municipal Utility District (California)	Utility
Missouri Department of Natural Resources (Missouri)	Government
Snohomish County Public Utility District (Washington State)	Utility
Southern California Edison (California)	Utility
Appliance Recycling Centers of America [ARCA] (Minnesota)	Recycler
JACO (California)	Recycler
BC Hydro (BC)	Utility
Appliance Recyclers of Canada Inc [ARCI] (Ontario)	Recycler

3.4 Data Analysis

Data was analyzed by reviewing documents and images and feedback from study activities. This information was then interrupted to help make recommendations for sustainable management within Manitoba.

Waste management frameworks for treating EOL refrigerators either: 1) adhere to strict regulatory code or 2) are voluntary and include participation from numerous stakeholders working towards common environmental goals. Significant time and resources are devoted towards developing specialized treatment technologies and implementing strategic management systems for reducing harmful impacts these appliances have on the environment. Whether these systems are truly sustainable is uncertain, but they do prevent pollution (halocarbon recovery) and minimize waste generation during the recycling process.

Despite progress, Manitoba lags behind frontrunners in this field of waste management. Its EOL strategy is criticized by many (especially those outside the province) as not being a strategy at all, lacking a co-ordinated vision for recycling refrigerators within the province. Municipalities manage refrigerators with little or no help from industry or the manufacturer, once they reach the EOL stage. A patchwork of over 200 individual municipal management systems has evolved – each with their own special criteria for disposal.

The objective of this chapter is to uncover areas of refrigerator management where gaps in policy, practice and procedure occur by providing a comprehensive review of refrigerator management within Manitoba, highlighting: provincial regulatory requirements, municipal management strategies, established recycling infrastructure and secondary appliance market. This is accomplished by presenting data obtained from reviewing relevant literature, multiple site tours (landfills, recycling yards, used appliance operations), stakeholder interviews and observations, electronic questionnaires, and roundtable discussions. This overview develops a baseline for research in the following chapters, which analyze waste management policies and treatment methods for applicability towards implementation in Manitoba.

4.1 Stakeholder Responsibilities

Table 4.1 introduces Manitoba stakeholders who are active in managing EOL refrigerators. These stakeholders are referred to throughout this chapter where their roles are described in greater detail.

Table 4.1: Manitoba Stakeholders: Roles and Responsibilities

Stakeholder	Role & Responsibility
Municipal Resident/Consumer	• Ensures appliance is delivered to appropriate public/private sector program for refrigerant recovery. • Consumers purchase energy efficient – environmentally friendly appliances.
Manitoba Conservation	• Enforce the *Ozone Depleting Substances Act & Regulation.* • Levy fines/penalties against those non-compliant with the Regulation.
Municipality/Waste Disposal Ground (WDG)	• Provide waste disposal service to its residents. • Act as a public sector program for appliance decommissioning and disposal. • Ensure compliance with ODS Regulation. • WDG – transfer center or storage facility for appliances waiting decommissioning. • Provide educational materials regarding proper EOL management techniques.
Certified Technician	• Obtain environmental awareness training and certification. • Act as private sector program. • Recover refrigerant from appliances prior to disposal/recycling. • Store and/or make arrangements for destruction of collected refrigerant.
Scrap Metal Recycler	• Recycle appliances into component parts.
Utility Providers	• Provide electricity to customers. • Provide incentives to customers towards purchase

	of energy efficient appliances. • Organize an appliance buy-back program.
MOPIA	• Provide environmental awareness training and certification. • Manage provincial records database.
Appliance Refurbisher/reseller	• Acquire and repair appliances for resale.
Producer	• No responsibility (physical and/or financial)

4.2 Regulatory Framework

Currently, no specific legislation exists within Manitoba, providing BMPs or policies towards managing EOL refrigerators. The *Ozone Depleting Substances and Other Halocarbons Regulation 103/94* [*Ozone Depleting Substance Act* C.C.S.m. O80] provides some guidance on refrigerator management, but focuses mainly on emissions and recovery of OSD and their alternatives.

4.2.1 The Ozone Depleting Substance Act

The Act recognizes that continued depletion of the ozone layer causes serious threats to human life and preventing the release of ODS into the atmosphere is key towards halting ozone destruction. The objective of the Act is to prevent, reduce and eliminate, in Manitoba, the environmental release of ODS into the atmosphere. Manitoba Conservation enforcement responsibilities and fines and penalties are highlighted within. For a first offence, the fines (per person) range from $50,000 and/or six months jail sentence (with $1,000 for every day out of compliance) to $100,000 fine and/or one year imprisonment for repeat offenders. For a first offence the fines for a corporation are $500,000 and a second $1,000,000. It should be noted, "Manitoba has among the highest notarized fines in the Act among all Parties to the Montreal Protocol" (MOPIA 1998:16).

These fines are designed to discourage future infractions given the potential for development of skin cancer (M. Miller, May 25, 2007).

In a precedent-setting case on ODS, the first in Canada (1993), charges were filed against WBS Construction of Winkler for failing to adhere to provincial ozone legislation. Six charges under the ODS Act were levied because WBS failed to properly recover CFCs from a refrigeration unit during repair. In court, WBS plead guilty to repairing refrigeration equipment without recovering ODS and was sentenced $2,000 and related court costs (Manitoba Conservation 1995).

4.2.2 *Ozone Depleting Substances and Other Halocarbons Regulation 103/94* [MR 103/94]

MR 103/94 principally controls emissions and discharges of classified[1] substances into the environment, establishes halocarbon recovery and recycling programs, and mandates environmental awareness training and certification. The following devices define white goods:

1. a domestic refrigerator or freezer;
2. a window air conditioner;
3. a 115 to 230 volt self-contained plug-in unit that requires the use of a Class 1, 2, or 3 substance for operation, including but not limited to a drinking fountain, a pneumatic air dryer, and a domestic dehumidifier.

Technically not waste management legislation, MR 103/94 serves as primary reference for EOL refrigerator management and must be adhered to when disposing appliances. Refrigerators can not technically be considered discarded until the equipment ceases to contain any refrigerant and can no longer be used for its original intention. If a unit still containing a refrigerant charge is deposited within a landfill for disposal – the equipment can still potentially be reused and is therefore not considered disposed of. To ensure proper disposal, no person shall dispose of any white good, without first making certain the refrigerant is captured for recycling, reclamation[2], or destruction. It is acceptable practice to deliver an unwanted appliance to a public sector program (i.e. municipality) or private sector organization (i.e. certified technician) that ensures refrigerant recovery.

Only certified technicians are allowed to perform work on refrigerators containing a refrigerant. To become certified, they must complete a one-day environmental awareness training class - *Fundamentals of Refrigerant Control*, administered by the *Manitoba Ozone Protection Industry Association* (MOPIA). Environmental and regulatory information regarding refrigerants is covered. Upon completion, a certification number is assigned to that person, who is now recognized as a certified technician.

When disposing of white goods in Manitoba, there are three main regulatory requirements that must be met, which are:

1. Technicians must ensure that decommissioning does not result in the release of a regulated refrigerant and have with them at a job-site functioning equipment capable of recovering and containing a refrigerant[3];

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[1] Class 1 = CFCs & Halons, Class 2 = HCFCs, Class 3 = HFCs & PFCs
[2] Reclamation refers to the recovery and purification of refrigerant to near new specifications (MOPIA 1994).
[3] One exception allows minute release of refrigerant during the recovery process when using a recovery hose less than 92 cm in length – a small amount will escape when disconnecting the hose from the tank (J & D Desroshiers, Apr. 18, 2006).

2. Recovered refrigerant that cannot be reused must be stored for destruction. Disposal typically costs $12.00 per pound and bore by the technician (regulation mandates seller take-back, but not from white goods sector)[4]; and
3. Technicians must keep a record data sheet detailing the type of equipment and work carried out, type of halocarbon being handled, and weather a halocarbon was charged or recovered from a system. Records must be submitted to MOPIA prior to February 1st each year.

Section 25 does not mandate decommissioning labels when disposing of appliances, but it is suggested practice within MOPIA's *Manitoba Compliance Guide* to identify evacuated equipment based on Environment Canada's Code of Practice.

Refrigerators cannot be converted back to CFCs although a special exemption from the Class 1 (CFC) refill ban exists, allowing recovery, repair, and recharging with its original CFC (because of the small amount of refrigerant the units operate with) (G. Kurwoski, July 19, 2007). If a system is modified from a CFC substance to an HFC, the certified technician must label the equipment accordingly.

A leak test must be conducted and if detected, the system must be immediately fixed or recovery of the refrigerant and deactivation to prevent further damage to the system (it is illegal to add halocarbons for leak testing).

4.2.3 Drawbacks to MR 103/94

MR 103/94 is not waste management legislation and does not effectively define roles and responsibilities for stakeholders other than certified technicians. Certain

[4] Storage is recommended within refillable and recyclable cylinders designed to safely contain, transport, dispense, and recover refrigerant. Storage should occur in dry areas away from any sources of heat.

aspects of public sector programs, including co-ordinating, financing, collection, transportation, storage and recycling are left undetermined. Municipalities are free to form their own compliance scheme and dictate responsibilities of stakeholders within their jurisdiction. This has lead to inconsistencies in management trends across the province – varying individual responsibilities from municipality to municipality.

4.2.3.1 Education and Public Awareness

Research indicates inconsistencies have negative impacts on expectations from the resident's standpoint making them feel out of compliance if their practices differ from neighbouring jurisdictions (Alderson 2004). Since residents roles are quite diverse across the province, they may not specifically know what is expected of them. Site visits to rural landfills showed residents may or may not be responsible for having the refrigerant recovered or paying EOL fees associated with disposal. Sixty-eight percent of municipalities responding to a Manitoba Conservation survey reported refrigerant recovery is the resident's responsibility prior to disposal, but it is uncertain whether this requirement is actually enforced in the responding municipalities (Epp 2002).

Public awareness is also a key issue. Less than ten percent of municipalities responding (5/123) to the Conservation survey reported they actively promoted or provided education to residents regarding management techniques or responsibilities (Epp 2002). A correlation exists between low levels of public awareness and a municipality's ability to offer effective refrigerator management services – as residents are inclined to illegally dump or vent refrigerant to bypass disposal costs (Alderson 2004). A discussion with a local landfill operator from the RM of Bifrost (June 7, 2007) illustrates this point. Ten years ago, BAR (Bifrost, Arborg, Riverton) Waste implemented a ban on white goods disposal, which translated into 10-15 refrigerators and chest freezers recovered per month from the ditch outside the landfill, some with the compressors removed. When asked what motivated residents to dispose of units in this fashion, he stated it was because residents did not want to pay for Freon removal. Even after the ban was lifted, allowing residents to drop off units free of charge, illegal disposal still continued because residents were unaware of the policy change. Had the residents known disposal was free of charge, illegally dumping would never have occurred in the first place.

4.2.3.2 Best Management Practices

BMPs related to management of refrigerators are absent from MR 103/94. It is difficult for municipalities to provide educational elements when they themselves have no procedural guidelines to follow. Critical practices regarding collection, storage, refrigerant recovery, emissions reductions, and what should be done with the degassed carcass – is not provided. During an interview, one municipal official asked if it was acceptable practice for white goods to be buried after decommissioning, as a growing scrap metal pile infringed on other disposal areas. Only 26% of municipalities responding to the Conservation survey said they sent their white goods for recycling, 35% "crushed" their white goods (with no end market) and eight percent sent appliances to landfill (Epp 2002). Failure to highlight the linkages between white goods and recycling actually places great strain on some northern communities, where it is often uneconomical for recycling companies to recover scrap metal from these locations –

burdening waste disposal ground with their storage.

4.2.3.3 Polyurethane Insulating Foams

Although release of regulated substances is prohibited, Section 5 of MR 103/94 does not address halocarbons routinely released from insulating foams during the recycling process, mainly because:

- **Priority**: recovery of blowing agents non-priority for Federal-Provincial Working Group. Appliances represent 1% (small fraction) of blown insulation usage – major uses: construction (L. Dalgleish May 7, 2007);
- **Cost**: specialized treatment technologies are extremely costly and require a constant feedstock of 300,000 plus units (R. Schade, July 12, 2007);
- **Resources**: manual disassembly requires labour, space, and time. More effective than open shredding but does result in small amount of emissions (M. Dunham, Jan 2007).
- **Code of Practice:** blowing agent recovery is not addressed within Environment Canada's Code of Practice.

4.2.3.4 Hazardous Components

No guidance on the hazardous elements, such as refrigerant oils and mercury switches, is provided.

Recovery of oil is not mandated during decommissioning, despite containing approximately 20% dissolved refrigerant. The Code of Practice recommends all equipment have both the refrigerant and oil fully recovered before disposal (Environment

Canada 1996) and Manitoba's *Fundamental's of Refrigerant Control* provides a best practice for a 95% recovery rate, which is rarely, if ever, used.

Many certified technicians and rural landfill operators interviewed were unaware chest freezers and washing machines contained mercury switches. In one municipality, standard practice dictated chest freezer lids be removed (for safety reasons) and then deposited within the scrap metal pile, increasing the chances of mercury contamination. No regulations exist within Manitoba for mercury switch removal and forthcoming federal regulations for the collection and treatment of mercury switches from EOL vehicles is on the horizon (K. Calder, Apr. 26, 2007). Therefore, major scrap metal recyclers are free to draft their own policies regarding mercury switch management from chest freezers.

4.2.3.5 Record-keeping, Labelling and Refrigerant Disposal

Record keeping gives provincial authorities the ability to track refrigerants currently in use and technicians must be able to show where every ounce of refrigerant was used. A grey area exists though when decommissioning white goods, as the refrigerant in these appliances is not tracked like bulk refrigerants – especially from historical units. Record keeping is then left to the "honour system" as any technician could vent the refrigerant into the atmosphere and choose not to keep records, as no one would be aware of their activities.

As previously stated, labelling is not required when decommissioning. Without proper labelling, proof of refrigerant removal cannot be shown (Environment Canada 1996). Manitoba's scrap metal recyclers rarely check for labels when accepting appliances - but rather severed refrigerant lines, which ensures no refrigerant is left within the unit. Previously, residents dropped off appliances for recycling without labels stated one was preciously attached and had fallen off. Also, technicians claimed refrigerant lines had puncture holes from the evacuation equipment, but could no longer find the hole. Recyclers argue that a label serves no purpose if the puncture hole cannot be identified (S. Lau, March 7, 2007). Scrap handlers can receive hundreds of white goods per day and do not have time to check each one for labels/puncture holes. Cut lines may seem like an effective method for identifying a decommissioned appliance however, it does not ensure proper refrigerant recovery.

All bulk refrigerants enter a product stewardship program run by *Refrigerant Management Canada* (RMC), a not-for-profit corporation established by the *Heating, Refrigeration, and Air Conditioning Institute of Canada* (HRAI) for the safe disposal of surplus refrigerant.

The main goals of the RMC program are to ensure the responsible disposal of surplus ODS stocks in Canada, prevent emissions of ODS into the environment, and the environmental management of ODS to prevent depletion of the ozone layer. The program mandates a levy, whereby refrigerant manufacturers, importers, and reclaimers pay a $1.50 fee on every kilogram of HCFC-22 sold. The levy helps to fund all aspects of the RMC program including collection, transportation, storage and destruction. The program allows for end-users to submit previously recovered or unused refrigerants (particularly CFCs) at any time (RMC 2007).[5] Since its inception (2001), RMC has

[5] The contractor transports the surplus refrigerant to the wholesaler at their own expense. The wholesaler contacts RMC Collection Service Provider for transportation of the surplus refrigerant for disposal. Refrigerant is checked for contaminants (PCBs, oil, etc) and ensures that submitted refrigerants qualifies for the program before transferring it to larger containers for shipment to destruction facilities (RMC 2007).

collected over 800,000 kg's and destroyed nearly 700,000 kg's of waste ODS (RMC 2006).

Despite preventing emission of nearly 530 tons of ODS, the program has several drawbacks. First, RMC is trade sector specific and does not recognize the white goods sector as a participant. Second, the program is focused mainly on the recovery and destruction of CFCs and HCFCs and does not account for other halocarbons such as HFCs. One frequent question encountered from technicians was "what can be done with recovered CFC-12?" Even though white goods can be recharged with CFC-12, most technicians stated they rarely reuse it as a refrigerant. This places the onus of proper disposal on the technician. The cost and time involved is a true disincentive, as venting refrigerant into the atmosphere is easier over long-term storage.

4.2.3.6 Enforcement

A Friends of the Earth (2001) study regarding ODS recovery programs from white goods in Canada, showed Manitoba poorly enforced the provincial regulation. Compliance is a municipal responsibility at their landfill and "enforcement is used only when necessary such as where there is obvious and continued failure to adhere to the regulation" (FOE 2001:6). For a person to be charged, they must be caught in the act of releasing refrigerant and the presence of cut refrigerant lines and no label may not be enough evidence to levy a penalty.

4.3 Provincial Disposal Estimates

Knowing the number of refrigerators that reach the EOL stage is critical to any management strategy as it determines how many units need processing, the quantity of halocarbons recovered, and the amount of revenue expected from recycling (Environment Canada 2004). An attempt to accurately assess the number of refrigerators disposed of each year in Manitoba has never occurred. Municipalities rarely record number of units received for disposal and is highlighted in the Conservation survey where no municipalities responded to the question of estimating number of units received per annum – requiring ODS recovery or with ODS recovered (Epp 2002). Given the total number of appliances entering the waste stream is unknown, estimating these quantities must occur.

Environment Canada (2004) provides a formula that encompasses all halocarbon containing white goods for calculating the total number of units discarded each year in a municipality. Results will vary throughout the province and depend on factors including size of municipality, income level of residents, climatic conditions of the region, etc. A ratio of 775 halocarbon-containing appliances per 100,000 residents is acceptable for calculations, with 70% of appliances discarded consisting of refrigerators. Table 4.2 provides a breakdown of white good types and the percentage of the waste stream they represent.

Table 4.2: EOL White Goods Generation in Canada for 100,000 Residents

Appliance Type	Percent of Waste Stream	Coolant per Appliance – Cooling Circuit (kg)	Total Weight per Appliance (kg)	Number of Appliances Discarded	Collected Coolant (kg)	Total Weight of Unit (kg)
Refrigerators	70	0.3	100	542	163	54,200
Freezers	20	0.3	80	155	46	12,400
Air Conditioners	5	0.5	45	39	20	1,755
Dehumidifiers	4.5	0.1	22	35	3.5	770
Heat Pump	0.5	1.8	20	4	7.2	80

Reproduced from: Environment Canada (2004)

With a population of 1.2 million, 9,300 halocarbon containing white goods are expected for disposal each year – with the majority, 6,510 consisting of refrigerators. Table 4.3 estimates the actual number of halocarbon containing white goods discarded each year in Manitoba, with the amount of halocarbons and scrap metal expected for recovery from each appliance category.

Table 4.3: EOL White Goods Generation for Manitoba

Appliance Type	Percent of Waste Stream	Approx. Number of Appliances Discarded in MB	Coolant Recovered (kg)	Total Weight of Appliances (kg)	Scrap Metal Recovered (kg) [Δ]
Refrigerators	70	6,510	1,953	651,000	475,230
Freezers	20	1,860	558	148,800	108,624
Air Conditioners	5	465	232.5	20,925	15,275
Dehumidifiers	4.5	418.5	41.85	9,207	6,721
Heat Pump	0.5	46.5	83.7	930	678
Totals	**100**	**9,300**	**2,869.05**	**830,862**	**606,528**

Modified from: Environment Canada (2004)

[Δ] Scrap metal constitutes 73% of the total weight of an appliance (Environment Canada 2004).

The City of Winnipeg (2007a) recently released a bid opportunity for EOL halocarbon-containing appliances, estimating 4,000 will be collected between 2007 and 2010. Brady Road landfill will receive 2,450 (2,100 refrigerators/freezers and 350 air conditioners) and 1,550 appliances collected from residential locations (1,500 refrigerators/freezers and 50 air conditioners). Actual numbers recorded for 2006, consisted of 2,556 appliances delivered to Brady Road and 1,129 collected from residences – for a total of 3,685. Table 4.4 breaks-down the number of appliances collected on a monthly basis for the City of Winnipeg in 2006.

Table 4.4: City of Winnipeg Appliance Collection 2006

Month in 2006	**Brady Road Landfill**	**Residential Requests**
January	77	45
February	68	33
March	120	57
April	309	94
May	277	106
June	317	131
July	331	117
August	228	162
September	254	125
October	306	141
November	174	65
December	85	53
TOTALS	**2556**	**1129**

City of Winnipeg (2007)

These figures fit well with the estimated disposal total using the Environment Canada formula. Several municipalities visited during this study reported handling between 30-35 halocarbon-containing appliances per year – taking into account some receive more than others (e.g. Brandon 100-200). If each municipality (excluding Winnipeg) averaged 30 appliances per year, it would amount to 6,030 units discarded. When combined with the actual numbers from Winnipeg in 2006 (3,685), a total of 9,715 is achieved. By averaging both estimates, 9,507.5 halocarbon-containing appliances including 6655.25 refrigerators are potentially discarded each year within Manitoba.

Green Manitoba (2005) attempted to estimate quantities of EOL white goods for 2004. Their estimates were based on a Waste Diversion Ontario (WDO) study. Estimating information technology, audio-visual, telecommunication, and household appliance disposal occurred, which was then prorated for Manitoba's population. Results showed 125,536 white goods discarded representing 10,465 pounds of waste. Table 4.5 shows white goods were the least discarded in terms of quantity, but represented the most in terms of overall weight.

Table 4.5: Prorated Waste Electronics Generation for Manitoba

	Units Discarded	**Tonnes Discarded**
White Goods	**125,356**	**10,467**
Portable Appliances and Floor Care Equipment	452,724	1,581
Information Technology Equipment	144,306	1,818
Telecommunications Equipment	238,717	101
Audio-Visual Equipment	414,431	4,744
Total	**1,357,714**	**18,712**

Reproduced from: Green Manitoba (2005)

Green Manitoba (2005) approved these estimates as appropriate numbers for Manitoba, however, it is difficult to accept them as fact since they differ significantly from the estimate generated using the Environment Canada formula. Distinctions between halocarbon and non-halocarbon containing appliances are not made, which makes it difficult to determine what percentage is made up of refrigerators and chest freezers in order to estimate halocarbon and scrap metal quantities.

4.3.1. Additional EOL Units: Retailer Recovery Programs and Appliance Refurbishment and Resale

An undisclosed number of EOL appliances end up within retailer recovery programs or are delivered directly to second-hand appliance shops for repair and resale. Most retailers have policies regarding old appliance removal when delivering new ones. Major retailer policies are left to the independent franchisee and are not dictated by head-office officials. Policies very between companies and usually focus on service fees or if delivery to rural areas is allowed (CAMA 2005). Sears Canada's policy only allows appliance removal when the customer purchases a delivery package:

- Bronze ($35): delivery of new appliance only;
- Silver ($50): delivery of new appliance and removal of packaging (from unit only), removal of old appliance from premises may be purchased for an extra $35; or
- Gold ($100): delivery of new appliance and removal of packaging (both from the unit and from the premises), removal of old appliance from the premises (Sears Canada 2007).

The Canadian Appliance Manufacturers Association (CAMA 2005) reports major retailers including Leon's, Costco, Sears Canada, The Brick, Home Hardware, Home Depot, and Futureshop offer appliance take back within Manitoba – each collecting fees varying between $10-100 for old appliance removal. Retailers rarely track and record the number of appliances collected – simply expressing collection as a percentage of new units sold. Most collected appliances are delivered to second hand repair shops and even if possible to estimate the number of old units collected, it is difficult to know exactly which appliances are resold and which are recycled. Unlike municipalities, who contract a single technician for decommissioning, retailers contract with two or more to ensure they receive top dollar for units delivered ($5-$10 depending upon the condition of the appliance) (CAMA 2005). Some units end up within municipal collection programs as a representative from the Brick stated all old appliances collected were taken to Brady Road landfill. Appliance resellers can also be very selective with the units they accept, leaving the retailer to potentially dispose of appliances through municipal programs or scrap recycler.

Most independent retailers (who account for nearly 20% of all new appliances sales in Canada) have appliance retrieval policies and usually enjoy higher recovery rates as this service is offered free of charge (creates a competitive advantage over major retailers) (CAMA 2005). Three independent retailers were listed from Manitoba in the CAMA (2005) study but did not provide any estimated numbers for appliance recovery (50% recovery rate was assumed), although most independent retailers across Canada reported taking back nearly 100% of older units when delivering new appliances. MOPIA estimates at least 75% of consumers in Manitoba buying a new refrigerator will have no use for the older unit they are replacing.

Appliance resellers deal with a number of sources including retailers, apartment complexes, residents, municipalities, junk collectors and scrap peddlers. CAMA (2005) states that white goods resellers play a crucial role in measuring material flows (between reuse and recycling) that are not accounted for by municipal programs. Resellers rarely track numbers of white goods received (as not all units are refurbished) and sales of used appliances range from 40 to 60 units per month and vary in age from new (off warranty) to 20-25 years old. One local reseller commented he receives 60-75 units per month, with 50% being decommissioned and 50% designated for resale. He often provides free decommissioning services in return for spare parts and recovered refrigerant (the owner or scrap peddler is then free to take the remaining carcass for recycling).

4.4 Used Collection Program: Manitoba Hydro 1991 Refrigerator Recycling Pilot

Only one program to date in Manitoba has attempted to address the resale market, the *1991 Refrigerator/Freezer Buy-Back Pilot Project*, which was a joint initiative between Manitoba Hydro, the City of Winnipeg, and Manitoba Conservation. It was designed to test the feasibility of instituting a refrigerator/freezer buy back program for the entire province. It focused on providing Hydro customers with a rebate credit on their accounts if they willingly decided to recycle their older refrigerator or freezer. A $30.00 rebate was granted if the older unit was picked up from the customer's home or $45.00 when the customer delivered to unit to the scrap metal recycler. If the customer was not able to deliver the unit to the scrap metal dealer, they were instructed to contact the City and request their unit(s) be picked up for delivery. The contractor picked up the unit at the desired location and took it away, providing the customer a voucher with their rebate credit. Customers who had two or more refrigerators and freezers in the Transcona and East Kildonan regions were targeted.

The goal was to achieve 290 units with total energy savings of 308.0 megawatt-hours/year (which works out to be 1,062 kWh/year/unit). Actual energy savings was far less at only 26.5 megawatt-hours (56 kWh/unit) actually saved, which is attributed to a number of factors. First, most of the appliances collected were older and smaller (8-10 ft^3), with manual defrost freezers (using significantly less energy than automatic defrosts). Original estimates projected higher volumes of automatic defrost units with a higher energy consuming value. Second, the program did account for households who replaced their older unit with a newer one. Finally, it was assumed that all units to be recycled were plugged in and running on a constant basis, however, this was not the case as some were only plugged in occasionally and others were not plugged in at all. The calculations were adjusted to take into account a reduction in household refrigeration would increase heating costs in the winter and decrease cooling in the summer. This is because "refrigerators and freezers add a quantity of heat to their surroundings and if the unit is removed the space heating load must increase to compensate while the space cooling requirements would decrease" (Morrison 1992:13). A typical refrigerator will expel as much heat as a 1000-watt heater running for several hours per day (Sunfrost 2004). Finally, not all units recycled were secondary units, as 25.8% of units were the primary or most often used refrigerator/freezer in the household (Morrison 1992). Manitoba Hydro is currently in discussions with MOPIA and other stakeholders for the development of a new secondary refrigerator/freezer buy-back program.

4.4.1 Appliance Power Smart Program

Manitoba Hydro is currently encouraging customers to purchase the most energy efficient appliances on the market by providing a rebate on specific *Energy Star* labelled appliances that meet energy efficiency *Power Smart* standards. Table 4.6 below highlights the rebate amount and criteria for the program.

Table 4.6: **Manitoba Hydro New Appliance Grants**

Rebate	Criteria
$50 on selected *Energy Star* refrigerators	*Energy Star* refrigerators that are between 10-20 ft^3 – refrigerators larger than 20 ft^3 are ineligible.
$25 on selected *Energy Star* freezers	*Energy Star* chest freezers that are less than 16 ft^3 in size – freezes larger than ft^3 and upright freezer models are ineligible.

Manitoba Hydro (2007)

4.5 The Provincial Framework

Municipal policies are developed around three main criteria, namely: 1) appliance acceptance, 2) EOL fees, and 3) collection/drop-off programs. Using these principles, along with the data collected, five general management frameworks appear to be prevalent, which can be seen in Table 4.7 below.

Table 4.7: Findings of Five Provincial Management Approaches with Combination of Fees and Acceptance

	Approach 1	**Approach 2**	**Approach 3**	**Approach 4**	**Approach 5**
Acceptance and Fees	Accept at landfill with Refrigerant – no fee (free of charge)	Accept at landfill with Refrigerant – disposal or recovery fee, or both	Accept at landfill only if refrigerant previously recovered - Free to minimal fee at landfill – may be fee for refrigerant recovery	No white goods accepted at landfill – fee N/A	Accept at landfill with Refrigerant – free to minimal fee at landfill
Municipaliti es	Springfeild, Winkler, Steinbach, Argorg	Winnipeg and Brandon	Thompson and Village of Dunnottar	None	The Pas and Flin Flon*
Refrigerant Recovery	Yes – onsite or at technicians workshop	Yes – onsite or at technicians workshop	Yes – at technicians workshop. Refrigerant may be vented by	N/A	No

			municipal officials		
Hazardous Component Recovery	No	No	No	N/A	No
Recycling	Yes	Yes	Yes	N/A	No
Collection	No – resident drop-off	Yes – arrangement with municipal office	Resident drop-off, with limited collection.	N/A	No
Education	No	Yes – limited through City of Winnipeg website	No	N/A	No
* Flin Flon has since instituted a white goods management program under the WRAPP Fund, which is discussed further below.					

Management approach one is perhaps the most effective strategy, as free disposal will achieve the highest rates of recovery and lowest incident of illegal dumping and venting of refrigerant. The downside is that refrigerant recovery is funded through taxpayer dollars, having those who do not use the program pay equivalent amounts of property tax (although the rich would pay more they would presumably have more refrigerators, freezers, and air conditioners). Although not as effective, Management approach two shifts the burden of refrigerant removal from the taxpayer to the resident, with only those who participate in the program benefiting. However, making the resident pay for decommissioning usually results in a high number of abandoned units or vented refrigerant. The only benefit to management approaches two and three is that the unit can be delivered directly to the technician for refrigerant removal, but these programs fail to achieve high recovery rates as it is a hassle for residents to seek out and deliver their appliance to the nearest technician. Framework five, the least prevalent management system, has no benefits associated with it as refrigerant is rarely recovered and units are not sent for recycling (occurs in isolated northern communities).

4.5.1 Approach One: RM of Springfield and Winkler

Residents of Springfield are free to deliver refrigerators to the landfill free of charge, still containing the refrigerant, which are stored in a specially designated area. Refrigerators make up the bulk of appliances and are stored side-by-side, right side up in two rows, with compressors facing inwards and a small corridor in-between. This is an effective set-up for decommissioning as aligning compressors allows the technician to recover refrigerant in the shortest possible time (three to four minutes per unit). Once the landfill accumulates 30-35 appliances, a technician is summoned to recover refrigerant and label units (municipality billed $10/ appliance). Refrigerant is recovered between spring and fall and the technician may visit twice per year depending upon the number of appliances accumulated. Once refrigerant is recovered, appliances are moved into a scrap bin for recycling (P. Goertzen Feb. 20, 2007). MOPIA received a phone call from a technician claiming to have had an exclusive contract with the municipality for refrigerant recovery. He alleged the municipality suspended his services and opted instead to cut lines and release refrigerant. A site visit to the landfill revealed no cut refrigerant lines on the stockpiled appliances.

The landfill operator in Winkler explained they chose to implement this type of program because it was the easiest way for the municipality to comply with provincial ODS regulations. They did not want to be fined for illegally processing white goods and felt that allowing residents to drop off appliances free of charge allowed for the best opportunity for compliance.

4.5.2 Approach Two: Cities of Winnipeg and Brandon

The Cities of Winnipeg and Brandon have implemented EOL refrigerator management policies that are variations of management approach two.

The majority of discarded refrigerators (69%) in the City of Winnipeg are delivered directly to Brady Road landfill still containing the refrigerant charge. White goods are considered 'bulky waste' (greater than five feet in each direction), and are subject to dumping fees, $4.00 for less than 1,000 kg and $22.50 for greater than 1,000 kg. Residents must ensure the appliance is properly secured during transport to Brady Road as solid waste by-law 1340/76 mandates a $50 fine plus disposal fee if waste is not securely fastened in place (City of Winnipeg 2007b). At Brady Road, residents deposit their appliance in the designated recycling area (scrap metal, used tires, used propane tanks, and appliances). Appliances containing halocarbons are segregated into their own area for easy identification by technicians – all other appliances are placed in the scrap metal pile (V. Jeancartte, Jan 23, 2006). This set-up does not prevent refrigerators from being improperly unloaded from a resident's vehicle. Refrigerators and freezers can be found strewn about and lying on their sides from being pushed off the back of trucks, which is why MOPIA estimates that nearly 95% of units collected from Brady Road are no longer in operating condition.

Residents unable to transport appliances themselves to Brady Road can make arrangements with the city to have it picked up from the curb of their home. A charge of

$10 for this service is added to the resident's water and waste bill and a third party contractor is dispatched to the home to retrieve the appliance (resident's responsibility to move the appliance from the home to the curb).

The City of Winnipeg (2007a), contracts to certified technicians for disposal of refrigerators, chest freezers and air-conditioners collected from residential properties and Brady Road ($10/unit). The contractor retrieves appliances three times per week from residential sources and must remove appliances a minimum of twice per week from Brady Road.

The contractor can extract the refrigerant at their facility or at Brady Road and is not required to enter resident's households to retrieve appliances. Once extraction has occurred, the contractor must affix a label to the unit and is then responsible for all recovered halocarbons and the disposal of the remaining carcass. Units can be delivered to a) Brady Road Landfill (no tipping fee for appliances degassed and labelled), b) a scrap metal dealer, c) appliance repair shop, or d) used appliance dealer.

It is evident, there is little public resistance towards paying EOL fees given the recovery numbers for 2006 (90% increase in drop-offs at Brady Road and 60% increase in residential collections over 2005) (T. Johnson, May 5, 2007). The only real drawback to the program, which several sources have noted (Alderson 2004, CAMA 2005) is that the Winnipeg's collection program is often hampered by scrap metal scavengers looking for appliances to be picked up by the city contractor.[6] Previous appliance recovery rates from households reached 97-99% and dipped only when someone at the contract administrators office tipped off a scavenger where and when appliances were to be

[6] It is assumed that when scavengers collect these units, the refrigerant is not properly recovered before recycling.

collected. When the problem was investigated, missing appliances were no longer an issue (G. Pantell, May 17, 2007). Others criticize Winnipeg's program as being an "optical illusion" stating the city only runs the program to show something is being done with EOL appliances. By listing used appliance dealers as acceptable locations for disposal, the city is not concerned with energy demand or climate change potential associated with reuse.

In Brandon, residents deliver the appliance, still containing the refrigerant, to the landfill where they are charged a decommissioning fee ($27) and a disposal fee ($5) -- $32 total for disposal. Appliances are deposited in a staging area for decommissioning and labelled onsite by a technician before being moved to a scrap metal pile near the front gate for recycling. Support for EOL fees is minimal and has led to illegal dumping. Refrigerators are often found in the quarry located near the auto wrecker, dropped at the gate of the landfill (after hours), placed in waste collection bins (bar fridge's, dehumidifiers, etc), or smuggled into the landfill hidden inside of other larger refuse. There is no responsibility for illegally dumped units, however, the city's public works department often collects abandoned units and delivers them to the landfill for decommissioning. Money collected from recycling often goes towards paying for decommissioning of illegally dumped units. One contractor remarked it was not worth collecting abandoned units for the scrap metal value because he could only fit six refrigerators in his half-tone truck and the $20-$30 dollars per load does not cover fuel, wear and tear on the vehicle, and wages (D. Muller, April 5, 2007). Some residents, who drop units off at the gate of the landfill after hours, can be identified on camera and tracked by their licence plate (I. Broom, May 2006).

4.5.3 Approach Three: RM of Mystery Lake/Thompson and Village of Dunnottar

Co-operation between the local technician and the landfill exists. A disposal ban on white goods containing refrigerant (once the unit is evacuated, the landfill accepts the unit for disposal) is in effect – so residents delivering an appliance to the landfill with refrigerant are denied from entrance and instructed to deliver the unit to the technicians facility. The technician charges the resident $35.00 to evacuate the unit and then drafts a letter of acceptance to present to the landfill operator, certifying the unit has been properly decommissioned and the number of units the resident is dropping off. The landfill charges a $5.00 disposal fee for every degassed appliance delivered. The contractor will cut a small refrigerant line leading off of the filter dryer signifying the unit has been properly evacuated (some landfill attendants will not touch refrigerators before they are put into the compactor for fear they still contain refrigerant) (M. Toporowsky Apr 4, 2007). Residents can also make an arrangement with the City of Thompson's Recycling Centre to collect the unit from the household at a cost of $35 dollars ($25 of that is given to the local contractor to decommission the unit).

This program has been unable to prevent the illegal dumping of units caused by the EOL fee. Refrigerators are left at the gate of the landfill and at the contractors' door during off-hours and units can also be found in the lagoon adjacent to the landfill (which is the responsibility of the Local Government District to collect). Prior to drafting acceptance letters, the local contractor previously wrote his certification number directly onto the units after refrigerant recovery. He remarked people started copying his certification number, clipping the refrigerant lines, and writing the number onto the units before delivering the appliance directly to the landfill. Even after instituting the letter of acceptance, photocopies were being made and passed off when disposing of appliances (M. Toporowsky Apr 4, 2007).

Several refrigerators with blatantly cut coolant lines were found at this landfill. They did not accept any white goods still containing refrigerant and it is up to the resident to find a technician for refrigerant recovery. The Village did not have a contract for this service nor did they provide any assistance to residents for seeking out someone to perform this task. When asked who cuts the refrigerant lines, the landfill attendant responded residents were clipping them before they dropped them off. He knew that cutting refrigerant lines was wrong and the large consequences related to venting refrigerant into the atmosphere (ozone depletion, climate change, etc.). However, stated that it is up to the Village to change their policies towards white goods – especially accepting them with cut lines. Given that each unit had its lines cut in relatively the same area it is easy to speculate that residents were not cutting the lines, but rather the landfill attendant either at the gate or in the scrap metal area once the unit was unloaded from the vehicle.

4.5.4 Approach Four

During the municipal landfill site visits, it was revealed that none of the municipalities had instituted complete bans on halocarbon containing white goods. All municipalities accepted white goods in some form or another.

4.5.5 Approach Five: Flin Flon and The Pas

Refrigerators are accepted at the landfill, however, they were often not being decommissioned and removed for recycling. A conference call was made with a member of the Flin Flon and District Environment Council and the head of the landfill, to discuss management trends in that community. It was explained that when refrigerators are accepted, they are stored in a segregated spot opposite the scrap metal pile. However, it was visible during the site visit that many refrigerators were being incorporated into the scrap metal pile. Refrigerators were not supposed to be mixed in with scrap metal, however, because of limited space and the expansion of the scrap metal pile, attendants were incorporating them into the pile (still containing the refrigerant charge) because there was no room left to have a specially designated area. The scrap metal pile has always been an issue for Flin Flon and requests to companies from Winnipeg to travel up north to remove the metal for free are made. They have been in contact with Manitoba Conservation and feel it is the government's responsibility to deal with these products (D. Oddeguard and G. Eastman, Feb 21, 2006).

In the Pas, there was no indication that refrigerators were being decommissioned once within the landfill. There was no segregated area for white goods and appliances were haphazardly strewn in amongst other scrap metal items. No attendant was on duty the day of the visit so it remains unknown how often, if ever, the scrap metal is recovered from the facility. The Pas did have a certified technician for white goods who charged $50.00 for refrigerant recovery, however, this service is rarely utilized because of the high cost to the resident, resulting in improper disposals (i.e. bush, fields, etc.).

4.5.6 Province Wide Trends

To target a wider audience beyond the municipalities and landfills visited during this study, a brief electronic survey was distributed by MOPIA (2005) to all municipalities in the province specifically asking if their jurisdiction operates a landfill and if they accept refrigerators and freezers. Thirty-one out of 202 municipalities (15%) responded to this survey. Seventy-percent (22) responded their municipality has a landfill – with 22% (5) indicating the landfill is shared with another municipality or town. Twenty-nine percent (8) indicated their municipality did not have a landfill, however, 80% (6) responded they operated a waste transfer station (WTS). Ninety-percent (28) responded they accepted refrigerators/freezers and other non-halocarbon containing white goods. Eight respondents simply listed their landfill/WTS accepted white goods and another three stated they accepted white goods that were separated and collected for scrap metal recycling. Five municipalities indicated that the appliance must have the refrigerant drained and labelled prior to delivery to the WDG/WTS. One municipality noted that if the resident dropped the appliance off without having the refrigerant removed – they would be charged the full cost of having it recovered. Another municipality remarked the only way they accept appliances at the WDG/WTS is if the refrigerant has been removed and a decommissioning certificate accompanies the unit from an authorized technician. Six municipalities stated they accept refrigerators and freezers at their disposal facilities (two that allowed free drop-off) and contracted with a technician to periodically visit and recover refrigerant. One municipality commented that industry should provide funding to have appliances properly handled instead of the municipality. One municipality replied that they accept refrigerators at their landfill/WTS, however, the scrap hauler is responsible for ensuring that the refrigerant is recovered prior to recycling. Several of the municipalities commented that revenues received from recycling of appliances/scrap metal were put towards the transportation of the metals to the recycling facility. Finally, three municipalities stated they were unsure of their appliance management policies as they shared waste disposal facilities with another municipality.

The Conservation survey (Epp 2002) reported that nearly 67% of the population of Manitoba (90% including the City of Winnipeg) has access to a municipally run ODS management program, with 59% (73/123) of responding municipalities having established ODS management systems. Most municipalities (68%) detailed the key tool in their program was having the individual resident responsible for recovery of ODS prior to disposal. The survey revealed that 85% of recovered ODS goes directly to the contractor, with 10% recycled and 5% destroyed. However, it can be assumed that 100% of recovered ODS goes directly to the contractor as only certified technicians are allowed to recover ODS (no municipalities reported having certified staff members trained in recovery of ODS). As for the remainder of the appliance, 74% responded that appliances are removed from the municipal landfill for recycling. The majority of municipalities (40%) send their scrap metal (including appliances) out for recycling on an annual basis (24% monthly, 3% weekly, and 33% other/unknown).

4.5.7 Funding for Refrigerator Management

In the past, funding designated for municipally run EOL refrigerator management projects was non-existent, with one exception. Currently, one municipality, Flin Flon, receives financial support from the Province for management of refrigerators. The Flin Flon and District Environment Council developed a project targeting the proper disposal of halocarbon-containing appliances. Refrigerators, freezers, and air conditioners are eligible for free transport to the landfill along with refrigerant recovery at no charge. A built in education program on the hazards of ODS is also included. The main outcomes of the project are to determine if it will 1) increase proper disposal of appliances, 2) assess the total number of appliances disposed of annually, 3) what are the real costs of the program, and 4) how the program could be funded in the future.

4.6 Manitoba's Recycling Infrastructure: Tours of Scrap Metal Recyclers

Three major scrap metal recyclers operate in Manitoba (General Scrap, Gerdau Amiersteel/Manitoba Metals, and Westman Salvage) accepting refrigerators for recycling. Two of these facilities were toured during the course of this study to assess their policies towards acceptance and recycling of refrigerators.

Refrigerators still containing coolant are unacceptable – General Scrap enforces this policy by ensuring every unit delivered to their facility has its refrigerant lines cut. Manitoba Metals perform limited spot-checks (by the load inspector) in the infeed area prior to shredding for refrigerant removal. Much of the feedstock received by Manitoba Metals consists of 2'x2' compacted bales of appliances, which makes it difficult to determine if a unit's compressor still contains a refrigerant charge. Since bales are received from all areas of North America, refrigerant recovery is dependent upon local requirements. Units delivered to General Scrap with refrigerant are prohibited from entry, with the onus of refrigerant recovery placed on the person delivering the unit. At

Manitoba Metals, if a single unit still contains refrigerant, acceptance is denied until it is properly recovered; they are developing policy for charging any unit still containing a refrigerant back to the supplier for refrigerant recovery costs plus administration fees (for those in bulk shipments).

Hazardous component policy differed significantly between organizations. General Scrap provides a booklet highlighting prohibited items and clearly indicates scrap containing mercury and/or capacitors is prohibited from entry onto the premises. General Scraps procedures for removing mercury switches from appliances is provided within the booklet and emphasizes the responsibility of the appliance crushers/recycler to ensure all mercury switches are removed prior to delivery to their facility and they must carefully place the switches in containers provided at the facility. General Scrap (2003) is committed to disposing of mercury switches through the most appropriate channels, which abide by all waste and transportation regulations. Manitoba Metal's policy on hazardous materials in appliances, mercury in particular, is less comprehensive then General Scrap. Given the number of appliances they handle, checking each unit for mercury switches is difficult and is not typically performed by load inspectors. However, once the federal regulation for EOL automobiles is implemented, appliances may become incorporated into the switch recovery program. In that case, Manitoba Metals would play an active role in the recovery process by providing training to workers for onsite removal. Both facilities have banned the acceptance of PCB containing capacitors and follow federal regulations for handling PCB contaminated wastes. Removal of refrigerant oils from compressors is not required at both facilities and Manitoba Metals stressed that because of the sheer volume of appliances they handle each year, it is extremely difficult to ensure that each one has been treated properly. No comments were made on the recovery of insulating foams and it is assumed that since the law does not require it, it is not a priority for these operations to invest the capital necessary to purchase BATs for treatment.

Both facilities used the open air method of recycling and once the ferrous and non-ferrous fractions were recovered plastics, foams, and glass were collected and sent to Brady Road landfill for use as daily cover or deposited on site to construct a sound-berm (K. Calder, Feb. 2, 2006, Apr. 26, 2007; S. Lau, Aug. 24, 2006, Apr. 5 2007).

4.7 Priority Areas for Refrigerator Management in Manitoba

To fulfil the objective of this chapter, an analysis of current policies, practices, and procedures in Manitoba has identified a number of significant gaps in the management strategy, which need addressing.

Lack of provincial waste management legislation: No true waste management framework or legislation for proper handling, processing, and treatment of EOL refrigerators exists in Manitoba. The only applicable legislation, MR 103/94, provides guidance for recovery of refrigerant only and does not address handling, transportation, storage and recycling of discarded units. The regulation also fails to highlight stakeholder responsibilities.

Uncoordinated management systems: Municipalities are obligated to manage refrigerators without any help from industry or manufacturers (cover expenses on their own either through municipal taxes or end-user fees). Municipalities are free to develop their own compliance scheme for MR 103/94, thus management differs from jurisdiction to jurisdiction (five general management approaches prevail). Criteria's differ for refrigerator acceptance at municipal landfills (i.e. with/without refrigerant, EOL fees, etc.). Ultimately, no provincially harmonized approach for management exists.

Public education for proper management techniques: Residents are not properly educated regarding refrigerator management, specifically what they should do with their unwanted appliance and are removed from the greater picture of ozone depletion and global warming and the negative effects of releasing refrigerant. EOL fees resulted in illegal disposal or venting of refrigerant, with most being unaware fee is for refrigerant recovery.

Municipal BMPs: There is no basis for municipal management strategies, i.e. guidebook for proper procedures on handling, transportation, storage, refrigerant recovery, recycling, etc. Municipal officials are not trained to identify, treat, contain, or mitigate potential hazards entering the waste stream such as mercury or PCB capacitors. In some cases, municipalities blatantly release refrigerant or are unable to send stockpiled refrigerators for recycling.

Institution of BATs: High cost of treatment methods and lack of regulatory priority for blowing agent recovery have deterred scrap metal handlers from installing them.

Other Issues: The total number of refrigerators discarded in Manitoba each year is not officially known and must be determined. There is no network for ODS collection and destruction from the white goods sector and most technicians are unaware of what to do with surplus refrigerants. Enforcement of MR 103/94 is lacking, which allows municipalities and residents to vent refrigerant without repercussions. Scrap handlers send potentially recyclable or reusable resources (plastics, glass, etc.) to landfill and energy inefficient appliances continue to be resold and draw electricity from the grid.

Chapter Five – Regulatory and Voluntary Approaches for EOL Refrigerator Management

This chapter aims to determine best practices, policies, and procedures for sustainable refrigerator management frameworks through analysis of regulatory and voluntary programs implemented in other national/international jurisdictions. This will be accomplished through reviewing relevant literature, tours of two refrigerator-recycling facilities (UK), issuing electronic questionnaires, attendance at ISWA 2006 Conference, and distribution of a Refrigerator Management survey.

Regulatory Approaches to Refrigerator Management

5.1 Refrigerator Management in the European Union (EU)

Like many waste management activities in the EU, management of EOL refrigerators and chest freezers is governed by a two-tiered regulatory system aimed at reducing waste and preventing pollution. To meet obligations to the *Montreal Protocol*, mandatory halocarbon recovery must occur from all refrigerators/freezers at their EOL. Furthermore, to meet rising electronic wastage concerns, producers of large domestic appliances must meet recovery/reuse/recycling targets of the units they produce and design products to lessen their environmental impact. Both activities require the use of BATs for sound environmental treatment.

5.1.1 *EU Regulation on substances that deplete the ozone layer* (EC No 2037/2000)

In 2000, *Council Regulation (EC) No 3093/94 on substance that deplete the ozone layer*, was redeveloped to include stricter control measures on substitute technologies for ODS. Under 3093/94 production of CFCs was phased out, but did not restrict them from being placed on the market or used in products or equipment. To strengthen the regulation, preventing ODS emissions and recovery of used halocarbons was needed. *EC Regulation 2037/2000* emerged on 1st October 2000 and currently applies directly to the recovery, recycling, and destruction of CFCs, in addition to, the importation, exportation, and placing on the market of products and equipment containing these substances.

Chapter 4, Article 16, Section 2 (*Emission Control - Recovery of used controlled substances*) sets forth mandatory EOL domestic refrigerator and freezer management after 31 December 2001. Member States are required to recover all halocarbons contained within for recycling, reclamation, or destruction before disposal of equipment by approved technologies. Prior to implementation, Member States were to report on the status of established infrastructure – including treatment facilities and amount of halocarbons recovered, recycled, or destroyed.

5.1.1.1 Requirements of 2037/2000

Eligible equipment: domestic refrigerators and freezers containing CFCs and/or HCFCs in either the cooling circuit or as a PUR blowing agent. Since the average life span of a refrigerator is 10-20 years the majority of appliances requiring treatment will contain CFCs. Any domestic appliance manufactured containing an HFC (R-134a) refrigerant and an HCFC (R-141b or 142b) blowing agent must still be treated accordingly. Non-CFC or HCFC (i.e. hydrocarbon [R-600], ammonia, or sulfur dioxide) appliances are exempt from this regulation.

Identifying domestic ODS equipment: all ODS containing equipment must be identified for treatment and can be done using the appliance rating plate. The metal plate or sticker will state the type of refrigerant contained within the compressor and after 1998, lists the type of blowing agent used in the insulating foam. Other more technical options exist to identify ODS in equipment including the pressure/temperature test (measuring the internal pressure of the appliance against the external atmospheric temperature and correlating the results) or the Beilstein or sodium fusion tests (chemical tests used to identify halides).

Refurbishment: EU countries are permitted to refurbish and resell refrigerators and freezers still in working condition. Leak-free units can continue to operate with a CFC refrigerant, however, if the coolant requires replacing it must be substituted with a non-CFC alternative and documented. Sale of refurbished equipment is strictly limited between EU countries and exports of products and equipment-containing CFCs (including insulation foam) is prohibited. Appliances not fit for refurbishment must be disposed of in an environmentally friendly manner.

Waste appliance recycling: refrigerators and freezers must be recycled in a contained environment. Exporting domestic ODS equipment to other EU member states for treatment with BATs is permitted, but subject to available processing room.

Waste management applicability – targets, etc: EU member states are not required to meet specific [solid] waste management targets – i.e. product recovery, reuse, or recycling – within the regulation. However, these specific waste management aspects for demanufacture programs can be set (DETR & DTI 2000, DEFRA 2001, UMIST 2002, DEFRA 2003, California DTSC n.d).

5.1.1.2 Implications of 2037/2000 on EU Member States

2037/2000 was enacted in European Parliament and immediately became enforceable as law in all member states (they do not have to pass individual internal legislation). EU regulations take precedent over national laws dealing with the same subject and subsequent regional legislation must not impede the objectives of the regulation (Wikipedia 2007a). Although stringent, member states were allowed flexibility when developing compliance schemes. They could determine how halocarbon recovery programs were promoted and who was responsible for compliance with the regulation (i.e. refrigeration technicians or a responsible [waste management] body). This includes defining the minimum qualifications for personnel involved in refrigerator/freezer demanufacture and refrigerant leak prevention programs (although may be subject to Council scrutiny). Most importantly, member states could develop their own criteria for refrigerator/freezer management by virtue of Article 16(7) of 2037/2000, which was developed not to interfere with Article 2(2) of *Council Directive 75/442/EEC on waste*, permitting individual states to adopt rules and regulations towards specific types of wastes.

5.1.2 *EU Directive on waste electrical and electronic equipment* (2002/96/EC)

Unlike 2037/2000, 2002/96/EC on waste electrical and electrical equipment (WEEE) is a directive that encourages member states to reach a desired result without influencing the outcome (i.e. member states pass their own domestic legislation) (Wikipedia 2007b). In this case, it recognizes the increase of waste electronics, many containing hazardous components, in the EU, which pose significant concerns for human and environmental health and waste management and recycling activities. The main objectives of the Directive are to prevent the generation of WEEE and to encourage recovery, reuse, and recycling to reduce WEEE disposal – by involving all entities involved in the product lifecycle – particularly producers, distributors, and consumers.

5.1.2.1 Requirements of *WEEE Directive*

Member states must ensure that producers meet the following requirements:

Separate Collection: minimize disposal of WEEE in unsorted waste, institute specialized collection areas. Free disposal for end-users (households).

Treatment: treat WEEE using best available treatment, recovery, and recycling techniques/technology.

Recovery: recovery targets set based on weight per category.

Reuse: priority is given for reuse of WEEE and its component parts – must meet reuse targets by weight of appliance per category.

Financing: products marketed after August 13, 2005 producers finance collection, recovery and treatment (invisible to consumer) – products marketed before subjected to an ARF.

Education: all products must be marked with a 'do not dispose' symbol, in addition to, providing consumers information regarding a) requirement not to dispose of WEEE, b) collection and return systems available, c) negative human and environmental health effects related to WEEE, and d) the meaning of the do not dispose symbol.

Demanufacturing: provide information on proper reuse and treatment techniques (i.e. dismantling procedures) and identify locations of hazardous components.

DfE: design products to facilitate demanufacture and recovery of component parts for reuse or recycling.

5.1.2.2 Implications of *WEEE Directive* on Refrigerator Management

Refrigerators, freezers, and air-conditioning equipment are listed as Category 1 appliances and therefore must be treated by producers accordingly under the directive. They must ensure product recovery reaches a minimum of 80% by average weight per appliance and minimum component reuse and recycling of 75% by average weight per appliance. Producers must ensure that all mercury switches, CFCs, HCFCs, HFCs, and hydrocarbons (HCs) are removed from collected WEEE. Domestic appliances containing ODS or substances with a GWP >15 in cooling circuit or insulation must be recovered and treated in accordance with 2037/2000.

Historical and orphaned white goods (i.e. products whose producer no longer exists) placed on the market prior to Aug 15, 2005 are subjected to a visible levy at point of sale, which allows the producer to show the full cost of treatment, collection, and sound disposal. White goods producers support visible fee's as their sector contains the most historical/orphaned products compared to other sectors (brown goods, IT, telecom, etc) and is seen as a cushion against the full impact of producer responsibility (Savage 2006).

Electrolux actively participates in the waste management of nearly 20 million appliances they sell in Europe each year – resulting in the design of their products specifically for disassembly and recycling. Specially designed recycling software optimizes product development and allows for cleaner production (purer plastics), incorporation of recycled materials (i.e. 60% recycled steel), and easily disassemblable polystyrene parts. Electrolux has phased-out CFCs, no longer utilizing HFC-134a as a refrigerant, but rather hydrocarbons, which are 260 times less potent a GHG than HFCs (Electrolux 2006, 2007).

5.1.3 Best Available Treatment Technologies

Both regulatory frameworks mandate the use of BATs for environmentally sound treatment of refrigerators, which entails the use of fully automated closed shredding systems for CFC, HCFC, and HFC capture. Several manufacturers market this technology (MeWa, SEG), which all utilize a similar three step treatment process:

5.1.3.1 Treatment Process

Step 1 - Pretreatment: the compressor and cooling system is drained of its CFC/oil mixture using an active recovery method. The mixture is then separated by thermal/pressure treatment with oil purity of 99.9% CFC free and the compressor is removed from system. Metal/glass shelving, plastic bins, magnetic gaskets, and mercury switches are removed.

Step 2 – Demanufacturing: units enter the recycling system via an airtight conveyor belt (5-10 units at a time) and are directed to the shredder. MeWa utilizes the Querstromzerspaner, which disintegrates (not shreds) and degasses (up to 98%) units all within this first step. The resulting fractions will range in size from 0.1-100 mm in diameter. MeWa captures CFC-11 using a cryo-condensation technique, where nitrogen gas is used to carry CFCs to the cryo-condensation equipment where –100°C to –160°C temperatures liquefy the CFCs to pressurized containers (150-180 m^3 nitrogen per hour is required). PUR is degassed with SEG systems by grinding the fraction and subjecting it to controlled heating, which thermally desorbs the ODS from the fraction. CFCs are then captured through an activated carbon filter system. With MeWa, all disintegrated fractions pass through a drying mechanism, which reduces moisture and drives off any remaining ODS, with the PUR sieved off immediately following drying. Ferrous and non-ferrous metals, and plastics are separated using conventional methods (magnets, eddy currents, etc.).

Step 3 - Secondary Processing: secondary markets for PUR are very limited, which results in its disposal after treatment. SEG has developed 'ÖKO-Pur', which reprocesses foam into pellets designed to mitigate oil and chemical spills.

Performance and Standards: these BATs have been analyzed to meet the following performance specifications.

- Recovered PUR halocarbons per appliance: 280g
- Recovered cooling circuit halocarbons per appliance: 115g
- Recovered oil per appliance: 300ml
- Halocarbon loss to process air: 125mg/unit
- Halocarbon loss to waste water: 25mg/unit
- Halocarbon loss to exhaust air: <20mg/m^3
- Halocarbon remaining in treated oil: <0.1%
- Halocarbon remaining in treated PUR: <0.2%
- Post-treatment PUR attached to ferrous metals: <0.1%
- Post-treatment PUR attached to non-ferrous metals: <0.25%

- Post-treatment PUR attached to plastics: <0.3%
- Ferrous fraction purity (no foreign material): 99.9%
- Plastic fraction purity (no foreign material): 95%
- Ferrous recovery rate: > 90%
- Overall Halocarbon recovery rate: >90%

SEG systems meet the RAL (German Institute for Quality Assurance and Certification) Quality Assurance and Test Specifications for the Demanufacture of Refrigeration Equipment Containing CFCs and MeWa systems are 100% fully compliant towards the *WEEE Directive* (RAL 2003, MeWa 2003, MeWa 2005, R. Schade Feb 21, 2006, SEG 2007).

5.1.4 Case Study: Policies and Procedures in Practice – the UK

To gain a better perspective of how the regulatory process has effected white goods management in Europe, in addition to, seeing first hand the policies and procedures developed to meet these regulatory requirements – tours of two refrigerator/freezer processors in the UK were undertaken (M. Baker Recycling and Sims Metal). The UK was chosen, over more environmentally focused/waste policy driven countries such as Germany (where fully automated fridge recycling was occurring ten years prior to 2037/2000), because of its similarities in management style to that of Manitoba's – as described in Chapter 2. It should be noted the tours took place **before** the UK implemented its *WEEE Directive* legislation, therefore policies, procedures and practices apply specifically to 2037/2000.

By virtue of Article 16(7) of 2037/2000, the main aspects of refrigerator/freezer recycling are controlled by the *Environmental Protection Act 1990* (c. 43), which stipulates that it is a persons duty of care in respect to waste that they will not:

- Handle or treat waste without a waste management license and in a manner likely to cause risk to human and environmental health;
- Allow the escape of waste from their possession; and
- Transfer waste without documentation.

5.1.4.1 Waste Management License (WML)

WMLs are granted by the Environmental Agency and allow for the storage and treatment of specified types of waste. Cost of WML depends upon the type of facility, waste to be treated, and amount of waste that can be collected. A WML for fridge/freezer demanufacture is 18.00 pounds. The WML outlines the obligations of the waste contractor (i.e. collection, costs, liability, recycling, record keeping, etc.), in addition to, obligations for clients (i.e. providing WEEE in acceptable conditions, fees payable, etc.). Schedule 2 of the WML outlines all conditions relating to EOL fridge/freezer management

5.1.4.1.1 Schedule 2

Specified Waste Management Operations: destruction of all appliances containing ODS must be undertaken in a contained environment. Storage of appliances containing oil and prior to pre-treatment must be done so on impermeable pavement and should not exceed three and a half meters or five refrigerators high (stacked on their sides).

Permitted wastes: only discarded equipment-containing CFCs, HCFCs, and HFCs – with associated hazardous components (mercury wastes and PCB transformers) are allowed onsite. Maximum total quantity of waste allowed for acceptance at M. Baker per year cannot exceed 79,999 tones. Maximum storage quantity at any one time cannot exceed 4,000 tones and can not include more than 20,000 waste refrigerators containing ODS. At Sims, total quantity of waste accepted at the site per year cannot exceed 74,999 tones.

Refrigerator Acceptance and Pre-Destruction Treatment: accepted appliances must be accompanied with a waste transfer note and cannot be mixed with existing waste refrigeration stock (units which have already been pre-treated). Refrigeration equipment must have the oil/halocarbon mixture in the cooling circuit evacuated to a 99% recovery rate. Oils must be treated to < **0.9**% dissolved ODS. After evacuation the compressor must be removed along with mercury switches and any accumulated water (condensation, etc.).

Refrigerator Destruction: destruction of fridge carcass must be done so in a contained environment to prevent loss of fugitive emissions and can not be destroyed if the cooling circuit has not been evacuated. Residual component materials must meet the following standards:

- PUR attached to metals: cannot exceed **0.5%**
- PUR attached to plastic: cannot exceed **1.0%**
- Halocarbon remaining in PUR: cannot exceed **0.5%** within contained environment and **0.2%** in an uncontained setting.

- Waste water can be discharged to sewers with no detectable levels of CFC-11
- Samples must be provided to the environmental agency every 50,000 units destroyed or 1-month.

Emissions Control: discharges of halocarbons to the atmosphere depended upon the amount of equipment processed per hour (M. Baker and Sims process approximately 60 units per hour): <100 units/hour – maximum emission rate of 5g/h.

Residual Waste and Output Storage: Table 5.1 below highlights the maximum quantity and storage times permitted for recovered hazardous materials and fractions from the demanufacturing process.

Table 5.1: Maximum Storage Allowances and Time for Recovered Fractions and Materials

Material	Maximum Quantity	Max Storage Time
Halocarbons (cooling circuit)	4 tones	6 months
Halocarbons (blowing agent)	2.1 tones	3 months
Compressor oil	11,000 liters	1 year
Ferrous metal fragments	125 tones	1 year
Glass shelving	18 tones	1 year
Non-ferrous metal	150 tones	1 year
PUR (briquette form)	50 tones	1 year
Plastics	100 tones	1 year
Magnetic Rubber Gaskets	20 tones	1 year
Compressors	100 tones	1 year
Reusable components	5 tones	1 year
Mercury Switches	10 tones	1 year

Records: records of waste moved and accepted, including types and quantity of units and if they contain a refrigerant and/or compressor must be kept. A daily log of each unit destroyed must also be kept and include the type of unit and date of destruction. Records should indicate the amount of refrigerant and blowing agents collected on a monthly basis and when applicable, records of wastes removed from the premises.

Other: commercial units are only allowed when capacity allows and no loose/bagged PUR is accepted for treatment (Environment Act 1990, Environment

Agency 2005, Environment Agency Wales 2005, M Baker 2006, R Holyoake April 2007).

5.1.4.2 EOL Management Process

The EOL management process begins with the resident, whose responsibility it is to deliver the appliance, free of charge, to a specially designated civic amenity site with their local authority (local authority exempt from obtaining a WML). The Environment Agency and Local Governments provide education for citizens regarding proper EOL management techniques. Local authorities prepare the waste equipment for collection and can assist with loading, but must ensure WEEE is in a clean state (i.e. no food residues, etc.). Sims and M. Baker have collection contracts across the country with M. Baker collecting daily from 40 sites (including a contract with Ireland). M. Baker has a fleet of eight collection vehicles (40ft 7.5 ton capacity) but will also subcontract to third parties.

When trucks arrive at the treatment facilities, waste haulers must complete all relevant paperwork (waste transfer notes, hazardous waste identifiers, etc.) for full accountability of the load being delivered. Trucks are weighed in and out. Fridge's are unloaded by hand from trailer (approx. 200 per load) using a forklift with a basket and sent to manual disassembly area where glass shelves, plastic bins, magnetic door gaskets, and mercury switches are removed.

The halocarbon/oil mixture is removed using an active recovery method and carcasses are sent for destruction in a contained environment (M. Baker = Erdwich system, Sims = MeWa system). Sims noted that the use of nitrogen gas was the most costly element of their fridge treatment system, even though its use is not a requirement under their WML. These facilities divert approximately 96% of component parts for recycling with the remaining 4% sent to landfill or incinerated (rubber gaskets [interfere with recycling systems] and PUR). As noted above, under 2037/2000, fridge processors were not required to meet recovery/reuse/recycling targets, but as third party recyclers would be subject to all targets and requirements under the *WEEE Directive*.

M. Baker sends a one-tone cylinder of CFC-11/CFC-12 for destruction every two months along with four drums of oil. Sims fills four – 150-kg tanks of CFC-11/CFC-12/HFC-134a for destruction every month. The halocarbon recovery efficiency of the MeWa system installed at Sims was calculated to a halocarbon emission rate of 1 g/h and 99% overall recovery efficiency (well within the standard limit of 5 g/h).

The Environment Agency will perform spot-checks for compliance, both random and scheduled. They audit all areas of the WML for compliance (i.e. meeting all stipulations). Waste transfer notes are audited on a quarterly basis, and third party waste haulers are audited for valid waste carrier licenses. This is in addition to providing test results for Emissions Control and Destruction Process Monitoring (J. Reeves, Sept 27, 2006; R. Holyoake, Sept 26, 2006; R. Holyoak, April 23, 2007).

Voluntary Approaches to White Goods Management

5.2 Voluntary Stewardship Initiatives

Regulation of refrigerator management in North America is rare, aside from landfill bans or coolant recovery (i.e. California's Public Resources Code, which bans appliance disposal and mandates recycling and CFC recovery), comprehensive regulations and producer involvement is lacking. What have evolved are voluntary stewardship initiatives for refrigerator management, which include participation from a number of stakeholders such as utility providers, transportation companies, appliance recyclers, and consumers. Utility providers offer consumers an incentive (typically monitory) to recycle their working secondary refrigerator before it reaches the EOL stage. This allows the utility to remove old, energy intensive refrigerators from the power grid, preventing them from being reused or resold and effectively recovering 'banked ODS.'

To fully understand the implications and effectiveness of voluntary initiatives, including policies, practices and procedures used for recycling refrigerators/freezers – a Refrigerator Management Survey was distributed to a number of North American jurisdictions currently operating a voluntary refrigerator-recycling program.

5.2.1 Refrigerator Management Survey

The introductory question asks participants if their area has a system in place for the management of EOL domestic appliances containing ODS. If yes, they could continue on to question two and complete the rest of the survey and if no they are directed to the non-management systems section (question 36 of updated survey).

Eight participants (five written, three phone) responded their area has a management system in place. Two of the written participants indicated no to this question – one being a governmental agency stating they are not responsible for operating appliance management systems, only enforcing the applicable laws (ODS, mercury switch recovery, landfill bans, etc.). The other participant stated they were not responsible for implementing a management system – but answered the remaining questions on behalf of their hired contractor.

Table 5.2 below highlights some of the key findings from the Refrigerator Management Survey:

Table 5.2: Refrigerator Management Survey Results

Section	Question	Outcome and No. of Respondents	Comments
Refurbishment	Is refurbishment encouraged for functioning appliances collected in the appliance-recycling program (ARP)?	**Refurbishment not encouraged** – 4/9 (44%) N/A – 5/9	• Refurbishment is not encouraged – units must be decommissioned. • One program, contractor verifies appliance is working and then disables it to prevent resale • Goal is to save energy from inefficient fridge's/freezers.
Collection	Programs target working secondary appliances – are primary units or damaged (primary or secondary) units accepted?	**Programs considering both primary and secondary units** – 4/9 (44%) N/A – 5/9 --- **Programs accepting only working units** – 5/9 (55%) **Programs accepting both working and damaged** 1/9 (11%) N/A 3/9	• Respondents noted that the scope of their program includes primary units – but 2/4 indicated the focus was primarily on secondary units. • All respondents said units **must** be in working condition – this is to calculate energy savings. • One program collected units (working or not) based on number of new energy efficient fridge's sold.
Incentive	Are incentives given to customers to encourage recycling of old units and purchase of new energy efficient	**Programs providing incentive to the customer to recycle old unit** **Yes** – 5/9 (55%) **N/A** – 4/9 --- **Programs**	• Most programs surveyed provide an incentive to the customer to recycle their old (working) refrigerator. Incentive ranges between $30-$50 (rebate cheque or utility credit) and depends upon

	models?	**providing incentive for the purchase of energy efficient appliances** **Yes** – 4/9 (33%)* **No** – 1/9 (11%) **N/A** – 4/9 *One Utility purchased new unit for customers.	• living condition (house or apartment) or type of unit (fridge or freezer). • Only three programs provided incentive towards the purchase of new appliances (one - $50 for *Energy Star* refrigerators). • One program – utility company purchased energy efficient model for low-income residents.
Decommissioning	Who is responsible for halocarbon recovery, what happens with recovered refrigerant and are refrigerant oils recovered?	**Recovery of refrigerant by Contractor** - 9/9 (100%) **Recovery of compressor oil** **Yes** 4/9 (44%) **N/A** 5/9	• All respondents stated that the contractor is responsible for refrigerant recovery (using active method) and refrigerants are either reused or destroyed. • Programs utilizing JACO/ARCA recover oils (required by law but rarely enforced). Oils are treated to reduce CFC content and are recycled for reuse – not classified as hazardous waste.
PUR Treatment	Are PUR foams recovered and treated to prevent halocarbon emissions?	**Yes** – 5/9 (55%) **No** – 1/9 (11%) **N/A** – 3/9	• Respondents indicating they treat foams for halocarbon recovery were partnered with either JACO or ARCA (appliance recyclers). • ARCA utilizes the Aldemann-55 processing machine that uses a negative vacuum to recover CFC-11 (condense and liquefy to 98.03 recovery rate). Residual fraction incinerated or disposed.

			• JACO manually disassemble units – scrape and bag foam – incinerated to burn electricity (7 kW/h fridge). • One respondent – independent of JACO or ARCA – indicated they did not recover foam-blowing agents and stated "no point to get excited about foam."
Manufacturer	What is the role of the manufacturer in your program and if not what should it be?	**Is the manufacturer involved** **No** - 2/9 (22%) **N/A** – 7/9 **What should the manufacturers role be** 4/9 (44%) N/A – 5/9	• Two respondents indicated the manufacturer is not involved in their program. • Four respondents indicated that it should be the manufacturer's/industries responsibility to properly recycle these products.
Conclusion	What is motivation for a good management system?	**Points for good motivation** 6/9 (66%) **N/A** – 3/9	• Sufficient funding for environmental objectives • Energy savings to the consumer • Reduce energy use • Utilizing an experienced contractor • Verification procedures to ensure requirements are met

- No answer (N/A) – respondents who did not provide an answer to the question (left space blank)

5.2.1.1 Discussion and Outcomes of Refrigerator Management Survey

The scope of most programs will include primary and secondary refrigerators (and often chest freezers), but priority is given to secondary units. All units must be in working condition to measure overall energy savings reductions and the cost of energy savings, showing the consumer the actual cost of running a second refrigerator. None of these programs take broken units into consideration and usually recommend making alternative arrangements for disposal (i.e. municipal or local government program) because broken units do not factor into energy savings calculations. Often, units must meet strict size requirements for program eligibility (i.e. 10-27 ft^3) and anything outside this range would be ineligible. In order to participate, residents must be a utility customer and are only allowed to recycle a certain number of units each year (usually 1-2 per household). Units are prohibited from reuse and must immediately be rendered inoperable.

Although quite stringent in requirements, these programs do excel at discouraging reuse. To remove appliance from service, ARCA severs the electrical cord, tapes shut or removes all doors, writes a large black X on side/front of unit in permanent marker (to deface unit), removes door seals, and breaks the temperature control mechanism. Despite these efforts, it was found that outside the scope of these programs, most retailers still collect and deliver appliances for reuse.

For voluntary programs, specialized appliance recyclers are best equipped for sound environmental management of used appliances, which includes recovering refrigerant and oils (for reuse or disposal), finding end markets for reusable/recyclable components (i.e. compressors, plastic bins, glass, etc) and treating PUR insulating foams. For oil recovery the CFC/oil mixture is collected into a separating unit where gravity separates the oil from CFCs – oil then degassed to further reduce CFC concentrations. To treat PUR foams ARCA operates the Aldemann-55 processing machine that uses a negative vacuum to recover CFC-11 (condense and liquefy to 98.03 recovery rate).

JACO is currently transitioning from a manual disassembly process (scrape and bag foams) to a fully automated SEG system adapted to accommodate North American sized refrigerators. Two participants listed the total amount of hazardous materials and resources recovered from their programs, which amounted to a combined total of 27,266.69 pounds of refrigerant, 5,367.73 gallons of refrigerant oil, 7,339.39 tones of scrap metal, and two pounds of mercury switches.

To determine total energy savings, several participants noted they used a net to gross ratio calculation, which varied between jurisdictions. Net energy savings for the program were dependent upon whether the collected unit actually reduced net energy consumption. If units collected were secondary units not being replaced then total gross savings were used. Within these calculations a number of considerations were made including what would the consumer have done with the unit if it was not collected within the program such as selling it to a used appliance dealer or keeping it as a secondary unit. One participant stated their net to gross ratio was 60% and another stated they saved 47.7 million kWh collecting nearly 48,000 refrigerators and 9,500 freezers. Two other participants stated they saved between 2.7-2.8 million kWh collecting 3000 units (913 kWh/unit).

Independent programs, not affiliated with specialized appliance recyclers, lack sufficient funding to address environmental treatment concerns (ODS/oil recovery, PUR treatment, etc). One telephone participant remarked that most independent programs only recover refrigerant, which solves only half of the environmental problem. This was evident from an interview with an independent program manager who stated they did not recover and treat PUR and he could not understand why people "get worked up about foams." Some participants indicated that it costs approximately $110-$135 dollars per unit (includes collection, transportation, decommissioning, recycling, disposal [ODS/waste fractions], administration, advertising, incentive, etc.) to implement a program. With this in mind, there was a clear need for manufacturer involvement, specifically to help with implementation of recycling infrastructure, cost of treatment and program administration.

One unique program saw the recycling contractor partner with the local utility – where the utility would contract the sale of new energy efficient appliances for low income households – the contractor would deliver and install the appliance in the residents home and remove the older unit for recycling.

Numerous suggestions were given on how to develop a successful voluntary management system including having strong verification procedures to ensure all aspects of the program requirements are being met (i.e. working appliances meeting size criteria) to guarantee a positive impact on the utility grid (reducing load, GHGs, etc.). It is also critical that management systems consider only one contractor for waste collection, treatment and disposal as it maintains consistency throughout the program by not duplicating efforts (i.e. communication, auditing, etc.). To be cost effective, the scope of the management system must be limited to only refrigerators and freezers – as the acceptance of other types of white goods (i.e. dehumidifiers and window/central air-conditioners) are difficult to justify. Two critical aspects include effective advertising combined with a multiyear program. The backbone of any voluntary program is promotion through advertising, where combining the utility bill with an insert usually results in the highest levels of participation. Multiyear voluntary approaches with repeated advertising campaigns have garnered the highest volumes of appliance recovery. Customer participation is predominantly influenced by incentive, typically a cheque for appliance retirement rather than on the purchase of new energy efficient models. Customers receiving a rebate cheque were more inclined to understand and appreciate the benefits of the program. New purchase incentives as a requirement for old appliance acceptance usually achieve the lowest participation rates as it targets only a small percentage of utility customers.

Overall, most respondents partnered with either JACO or ARCA. Based on responses received, there should have been more participants from independent programs – specifically to see if PUR foams are being treated.

5.3 Further Voluntary Initiatives

In the US, legislation requires only refrigerant removal prior to appliance disposal and does not consider PUR foams – although Section 608 of the *Clean Air Act* suggests the EPA could implement measures to make this activity mandatory. However, in the absence of regulations, the EPA has initiated voluntary efforts to increase recovery of PUR foams by promoting the environmental benefits of recycling old refrigerators – primarily the fact that foams are one of the largest preventable sources of GHG emissions. These voluntary initiatives target a number of key stakeholders including utilities, retailers, manufacturers, and recyclers (who have established the necessary infrastructure for treatment) and have spurred the development of the Insulation Technical Advisory Committee, which is evaluating the fate of current HCFC blowing agents for replacement (Kenny 2004).

5.4 Chapter Summary

To briefly summerize, this chapter looked at analyzing the two main management strategies for refrigerator recycling along with their policies, practices and procedures utilized within mandatory regulated programs and voluntary initiatives. In Europe (UK), regulations have targeted all refrigerators containing ODS and their alternatives for mandatory treatment before disposal and now include the producer in waste management and product redesign. North America, which rarely regulates the management of refrigerators, relies upon voluntary initiatives for recovery and treatment, involving stakeholders from various sectors. A comparative analysis of the effectiveness of each management strategy is presented in Chapter Six, section 6.2.2 *Assessment of Regulatory and Voluntary Management Frameworks.*

Chapter Six – Conclusion and Recommendations for Improving Manitoba's Refrigerator Management Policies, Practices and Procedures

6.1 Project Summary

The advent of CFCs ushered in a new era of safe refrigeration – a stable, non-toxic and non-flammable substance now replaced hazardous ammonia and methyl chloride. Little was known about the destructive properties of CFCs as their use expanded to a variety of other domestic and industrial applications. Speculation over chlorine's ability to destroy ozone molecules produced numerous theories, including Rowland and Molina's penultimate 1975 *Nature* article, which was later proven through the discovery of the ozone hole. Globally, the *Montreal Protocol*, has eliminated use and manufacture of CFCs, however, many problems still exist as these substances are banked within old appliances. Their replacements, HCFCs and HFCs, although less harmful to the ozone layer, are extremely potent GHGs and must be treated in the same fashion (recovery for reuse or destruction).

Globally, multiple waste management frameworks have emerged for managing halocarbon-containing domestic appliances, some mandatory and others voluntary – each utilizing a different policy strategy and tools. In Europe, a system of mandatory regulations has evolved to effectively shift the burden of management away from local governments and end-users to product producers and specialized treatment agencies. In contrast, North America, which has not regulated refrigerator management (nor included the producer in waste management activities), relies on voluntary initiatives for EOL management and treatment.

Through this research process that included a literature review, site tours (Manitoba & UK), consultations with Manitoba Stakeholders, roundtable discussions, ISWA 2006, and the distribution of a survey and electronic questionnaires – the four objectives of this project were met as stated in Chapter One. These objectives 1) identified most critical issues of refrigerator management and current waste management policy frameworks; 2) reviewed Manitoba's current refrigerator management system to identify gaps in policy, practice and procedure; 3) determined best management frameworks for sustainable refrigerator management; and 4) recommended most feasible management structures for sustainable refrigerator management implementation in Manitoba.

The most helpful aspect of this study was being able to learn first hand from site tours and interviews. Establishing management trends in Manitoba and the UK through interactions and observations with field managers proved more effective overall for making recommendations than simply reviewing the literature. In Manitoba, the perspective that all municipalities manage appliances in the same fashion was significantly altered as in fact each one uses a different approach – although this type of system is unsustainable. Witnessing first hand how strict policies and technologies have shaped management in the UK shows that this is the key necessary for reaching the next level of sustainable management. The survey provided excellent information on how voluntary buyback programs operate and highlighted essential points for successful programs. In hindsight, however, the survey contained too many open-ended questions, resulting in a lot of people skipping questions. Interpreting long-winded answers for open-ended questions made summarising a difficult task. While for other questions, little to no information was provided. If the survey were to be redone, it would be shortened to a few key questions and administered over the telephone rather than electronically.

6.2 Conclusions

6.2.1 State of Refrigerator Management in Manitoba

Refrigerator management in Manitoba is chaotic, resulting in lost CFCs and limited recycling of other components. Individual municipal management strategies, each with their own criteria for appliance disposal, have created confusion for residents looking to discard their old units. Lack of public education and uncertainty over their role has led to venting of refrigerant and improper disposals. Furthermore, municipalities are unaware of BMPs, which also leads to the escape of refrigerant and hazardous materials. At the political level, there is no waste management legislation specifically targeting refrigerators and mandating use of BATs to capture halocarbons and ensure all component materials are recycled. Also, a flourishing secondary appliance market has extended the life of old units – prolonging the use of ODS and energy inefficient refrigerators.

6.2.2 Assessment of Regulatory and Voluntary Refrigerator Management Frameworks

When assessing and comparing the effectiveness of the two different management frameworks for EOL refrigerators (regulatory vs. voluntary), this study has found that:

Regulations have a broader scope and impact than voluntary measures: EU regulations target all EOL refrigerators/freezers for mandatory treatment – whereas voluntary 'bounty programs', secondary units are favoured and appliances must meet specific criteria in order to be recycled (i.e. working condition, plugged in, etc).

Regulations establish standards and targets: EU member states set the ODS recovery standard including daily emissions limit (x mg/h), purity of foam and foam attached to metal and producers must also meet recovery/reuse/recycling targets for component materials. Voluntary programs do not usually consider ODS recovery or waste management targets but may set electrical savings targets.

Regulations facilitate BAT/BMP implementation: BATs are required in EU member states for processing and containing ODS insulation during demanufacture (capture and condense CFC-11) – BATs achieve higher rates of ODS and component recovery than minimum standards. Only voluntary programs partnered with specialized appliance recyclers (ARCA/JACO) make use of BATs – many independent programs fail to implement BAT/BMPs for foam treatment or oil recovery (limited funding - not cost effective).

Regulations can involve producers and drive DfE: EPR has shifted responsibilities for treatment to producers mainly through collection and processing at no cost to the consumer, along with educational campaigns for proper recycling techniques. Internalizing costs allow producers to design products with less environmental impact (i.e. single type plastics, less components, and hydrocarbon refrigerants). Currently, no producers participate in voluntary programs.

6.2.3 Goals for Sustainable Management

Based on an overall review of systems, policies, practices, and procedures, a truly sustainable management framework must incorporate the following:

1. Address all units being discarded;
2. Relieve end-users and/or local governments of physical/financial management of EOL refrigerators;

3. Implement policies with clear goals, stakeholder responsibilities, and appropriate policy tools (i.e. landfill bans, ARF, waste transfer notes, etc.);
4. BATs minimize harmful environmental impacts ;
5. Implementation of manual and automated disassembly techniques to recover highest percentage of resources;
6. Provide incentives for effective product recovery; and
7. Encourage the design of products for easy disassembly and reduced environmental impacts through incentives, bans or regulation.

6.3 Recommendations

This thesis offers three recommendations, one preventative and two reactive to resolve some of the unsustainable issues identified in Chapter Four. The first looks at transitioning the sale of high ODP/GWP refrigerators to environmentally safer substances such as hydrocarbons. The second recommends the implementation of a regulatory framework for management utilizing the principles of extended responsibility (but requiring political will). Finally, in the absence of regulation or working program, a short-term voluntary program is recommended to provide tangible environmental benefits.

6.3.1 Preventative Approach for Refrigerator Management

Whatever program results for EOL management, the sale of high ODP/GWP refrigerators (either new or used) should be phased out and replaced with hydrocarbon-based systems. Although this does nothing to currently reduce the environmental impact of old refrigerators, it does help in the long run to reduce current impacts in the future. This technology is already established in Europe and the trend there is to phase out the use of any substance with a GWP of >150 (in 2012 all mobile air-conditioning will be converted from HFC 134-A to carbon dioxide and other hydrocarbons) (Vainio 2004). Studies have shown that hydrocarbon technology can be just as energy efficient as HFC-134a based systems. Manitoba Hydro could provide incentives to customers under its appliance program to purchase environmentally friendly alternatives.

6.3.2 EOL Implementation of a Regulatory Framework

The most effective means of improving the sustainability of Manitoba's refrigerator management strategy would be to implement a waste management regulatory framework that would 1) target all EOL units across the entire province, 2) prevent air pollution, 3) reduce waste, 4) implement BMPs/BATs, and 5) provide public education. Using the two regulation European structure as a guideline, Manitoba could implement the waste management aspects under the *Waste Reduction and Prevention* (WRAP) *Act* and address halocarbon recovery by amending the *ODS and Other Halocarbons Regulation.* The specific policy tools and regulatory strategy is discussed in the following sections.

6.3.2.1 Policy Tools for Effective Refrigerator Management

A combination of different policy tools would provide the means to implement all regulatory aspects and could include a landfill ban, advanced recycling fees, standards (for procedures, equipment, and ODS recovery), targets (for waste management), eco-rebates and eco-labelling to influence people when buying new appliances. The applicability of each policy tools towards a refrigerator management regulation is discussed below.

Landfill ban: increases recovery rates for highly recyclable products and have been an effective tool for refrigerators and other white goods in 19 US jurisdictions (CAMA 2005). Ban can also be expanded to light shredder fraction (plastics, glass, foams) although might be difficult to enforce as markets may be limited (Lambert & Stoop 2000).

Advanced recycling fees: applied at the point of appliance purchase would be highly beneficial to establish a proper recycling infrastructure in Manitoba (should reflect all aspects of management). Several US states have applied $2-$3 ARFs for white goods in addition to the $17 and 20 Euro fee applied to refrigerators in Belgium and the Netherlands prior to the *WEEE Directive*. Under *WEEE Directive*, mandatory ARFs are required on the sale of white goods marketed prior to August 2005 (white goods represent largest category of historical/orphaned products) (Short 2004, CAMA 2005).

Eco-rebates: award 'green procurement' and consumers who purchase environmentally friendly refrigerators (either low ODP/GWP hydrocarbon based or low energy input units).

Eco-labeling: for consumers, label new units with information regarding environmental impacts (educate) and for industry, information for proper handling, dismantling, and identification of hazardous components – mandatory under the *WEEE Directive*.

Standards and targets: establish minimum values for product recovery, waste diversion and recycling. In Europe, governments establish minimum standards for ODS content in coolant, oil, PUR, exhaust air, and waste water in addition to, PUR attached to ferrous, non-ferrous, and plastic fractions. Targets have been established for appliance recovery and component reuse (i.e. *WEEE Directive* 80% recovery and 75% reuse/recycling and Dutch *White and Brown Goods Decree* 75% recovery/recycling for all refrigerators).

6.3.2.2 Regulatory Strategy – Amended 103/94 and Stewardship Regulation

MR 103/94 could be amended to strengthen the position of zero emissions by mandating the recovery of all halocarbons in domestic appliances including recovering coolant, blowing agents, and ODS saturated oils. Standards for emission limits, recovery levels, and treatment specifications (i.e. PUR purity levels or PUR attached to fractions) are a necessity and can reference established practices (i.e. RAL standards for decommissioning of CFC containing equipment). In addition, an amended MR 103/94 must define proper channels for disposal of recovered ODS, such as who is responsible for disposal and where refrigerant can be sent for destruction (i.e. facilitate partnership with RMC or Swan Hills). These amendments should specifically apply to product stewards, as described below.

To establish a stewardship regulation for refrigerators in Manitoba, a course of action similar to the process described in Chapter Two would be followed. Refrigerators would be defined as the designated material, with the remainder of the regulation outlining the various stewardship responsibilities related to management. They would include product management, establishment of a province wide collection system, identification of costs, administration of educational and point of sale programs, engagement in research and development, and providing training related to managing EOL refrigerators.

Stewards would be defined as anyone selling refrigerators or chest freezers in Manitoba and are ranked based on their position along the product chain: manufacturer (if not in Manitoba), distributor, Manitoba retailer (any major appliance retailer i.e. The Brick or Future Shop), organization, or individual (purchasing product outside province). This may also include voluntary stewards (i.e. brand-owners or manufacturers). Stewards form an Industry Funding Organization (IFOs) and develop a management system and funding scheme. The IFO contracts management to an operator, which for the case of refrigerators, should be an experienced appliance recycler such as ARCA, ARCI, or JACO – who are best equipped with the necessary BAT to recover halocarbons and recycle component parts. The operators would then work with municipalities to set-up collection depots, which are usually found at municipal landfills (municipalities can then institute landfill bans or develop segregation policies). Stewards must ensure that EOL units are accepted free of charge at collection points.

The IFO determines if an ARF is necessary, and if so, money collected is based on the plan for managing the designated material, i.e. expect to process x amount of material/year and will cost $x.xx amount to do so. ARFs would be applied to sale of new refrigerators and freezers for recycling today's historical and orphaned units. IFOs should try and get actual costs for managing designated products (i.e. management of combined refrigerators and chest freezers 8,856.75 units @ $113.00 per unit [to properly manage] costs approximately $966,912.75, therefore, a $36 levy on the sale of approximately 27,000 new refrigerators sold in Manitoba each year would be needed to cover actual recycling costs) (T. Johnson, Nov 5, 2007). Although when determining the ARF, the IFO should take into account the costs necessary to process and manage different sizes and brands of refrigerators (i.e. ARF reflects different size categories, etc.). The IFO would be responsible for approving the use of BAT/BMPs through research and development and would look for most cost-effective approach.

6.3.2.3 Pros and Cons for Implementing Stewardship Regulations

Stewardship is not extended producer responsibility, as it does not hold the producer physically or economically responsible, but is currently the framework or operating system in place in Manitoba and Canada. Although full EPR is preferable in, Canada and Manitoba these principles must be embedded within the existing product stewardship framework. In any case, extending waste management responsibilities in Manitoba can offer the following positive aspects:

1. An effective framework for transferring the physical/financial burden of waste management of refrigerators from the municipality and/or end-user to consumers and industry stakeholders. In the process, the 200 individual municipal management systems would be replaced by a single, province wide strategy focused on implementing environmentally sound policies for management.
2. Control measures by reducing number of stakeholders handling the product. Previous confusion over stakeholder responsibilities towards ODS recovery often led to vented refrigerant (as product moved between end-user, municipality,

certified technician, and recycler). An IFO funded contractor, such as ARCA, JACO, or ARCI would add a sense of control, as they would be the lone entity responsible for collection, decommissioning, and treatment.

3. A platform for implementing BMPs/BATs for sustainable management with a number of practices learned from the UK study tours and Refrigerator Management Survey could be utilized. For example, waste transfer notes would be beneficial to ensure all units collected from a particular location are transported and delivered for EOL treatment. Storage requirements, such as impermeable surfaces and stacking limitations, for collection depots and treatment centres would help to prevent refrigerant release and disorganized storage. Depending upon program operator, PUR foam treatment can be handled via BATs or alternatively through manual disassembly with only minimal loss of ODS – PUR destruction can coincide with refrigerant disposal.
4. Increased public education and industry training for proper EOL management techniques. Specifically, what steps should residents take when disposing of an appliance and where does the appliance go once it is disposed of? Like the *WEEE Directive,* stewards should promote the use of collection and return systems available and must connect consumers with larger issues such as ozone depletion and global warming.

However, unfortunately, as discussed in Chapter Two, product stewardship has a number of flaws, which would ultimately hamper sustainability - specifically it fails to involve the producer in EOL management activities and is therefore not a true producer responsibility program. There is no feedback mechanism or incentive to producers for product redesign and IFO determined ARFs would only reflect the cost of management and not research and development activities. As established in Chapter Two, Lambert and Stoop (2000) stressed that when recycling complex products such as refrigerators, policies not providing feedback to producers are destined to underachieve or fail. Examples from Sachs (2006) and Walls (2006) pointed to the shortcomings of several European refrigerator-recycling initiatives, which failed to differentiate product design and only considered recycling costs that did not provide feedback incentives for redesign. In addition, the current stewardship platform fails to account for performance measurements, specifically waste management targets. Setting and achieving targets has proven to be an integral part of many product/producer management schemes as seen within the *WEEE Directive* and the success of refrigerator recovery in the Dutch *White and Brown Goods Decree*.

6.3.2.4 Applying EPR Principles to Stewardship

Even though stewardship is not a true EPR type program, it is the existing context for extending product responsibilities in Manitoba. Despite its drawbacks, the Manitoba stewardship strategy must progress towards involving producers in the waste management of their products to internalize the externality and drive environmental product redesign – a measure the stewardship framework fails to provide. One only has to look at the success that EPR principles have had within product stewardship in BC, where industry producers have helped to close the feedback loop by internalizing costs that has driven product redesign. Therefore, a new framework for stewardship in Manitoba must evolve for greater sustainability, involving producer responsibilities towards financing and waste managing the products they market, which can help towards designing a more recyclable refrigerator that utilizes climate and ozone friendly substances. A good first step would be to include CAMA (the appliance manufacturers association in Canada) in the management process.

6.3.3 Implement a Voluntary Bounty Program

Acknowledging the lack of political will, awareness and focus on refrigerators at this time in Manitoba and Canada the more feasible approach and possibly a short-term program to adopt would be a voluntary bounty initiative.

Although voluntary bounty programs may not be the most effective from an environmental standpoint, they do provide some environmental benefits, which "is better than nothing" in the total absence of regulations or working program. Voluntary bounty programs are limited in their scope (working – usually secondary units with size restrictions and limitations on the number of units eligible for the program), and so are applicable to only a small percentage of refrigerators reaching the end of their useful lives (possibly only 1-5% of EOL units). Lacking political guidance, this type of program is the most logical step towards improving management within Manitoba, with Manitoba Hydro acting as an implementing agency under the Power Smart program. In fact, advanced discussions are progressing towards a four-year Manitoba Hydro run voluntary program. It should be stressed, however, that a program of this nature should only be considered as a first step to implementing a broader, more comprehensive, refrigerator management strategy. As established, these programs fail to address broken units, often neglect primary units and chest freezers and can lack funding for proper environmental treatment. Furthermore, proper management of refrigerators at the municipal level is not addressed. The fear is that if this course of action is taken, it will actually stall attempts for a full management program, as something is seen as already being done.

If a voluntary program is to be implemented within Manitoba, a number of the following principles should be met:

- Ensure at least compressor coolant and oil is recovered (25% of total ODS) - with proper destruction;
- Resource recovery and recycling;
- Preventing unit reuse – saves electricity and prevents additional GHG release through electrical generation - also prevents ODS from being released 'down the line';
- Retailer involvement – retailer collects units from customer and delivers it directly for EOL treatment – permanently remove old units from service and prevent their reuse;
- Partner with reliable appliance recycler – JACO/ARCA/ARCI utilize practices and procedures to reduce environmental risks – including PUR insulation foam treatment;
- Expand scope of project to include non-functioning units – although not contributing to electrical consumption – still a source of hazardous components and recyclable material;
- Provide a primary incentive to the consumer to recycle older unit and piggyback new purchase incentives after customers recycle old unit.

To be successful, this type of program needs a robust advertising campaign linking the environmental and economic benefits of recycling an old refrigerator (i.e. a utility bill insert stating that recycling saves money and reduces ODS emissions and GHG generation). A multiyear campaign, linked with consumer incentive, is the most effective way of gaining high customer participation and unit recovery. Although not cost effective or positively impacting the electrical grid, a voluntary program in Manitoba must consider broadening its scope to improve sustainability. Primary and broken units, chest freezers, and numerous other white goods containing halocarbons (i.e. window/central air-conditioners, dehumidifiers, etc.) have significant environmental impact potential and should be addressed in some capacity. If not within the buyback program then within a separate program, perhaps working with municipalities and providing an eco-rebate to those deciding to recycle a unit outside the scope of the buyback program.

6.3.4 Additional Recommendations

Short-term policy tools that may assist towards reaching the replacement of halocarbon containing refrigerators are eco-rebates and eco-labelling to help consumers identify with new environmentally friendly products. It would also be recommended to not deliver old refrigerators to municipal programs, but instead 'bank' the ODS contained within the cooling circuit and foams until an appropriate program is initiated for sound environmental treatment. Old refrigerators could be unplugged further reducing their environmental impact.

6.4 Final Thoughts

Refrigerator management in Manitoba is currently unsustainable – ODS and other halocarbons are released, recyclable resources are sent to landfill, and old energy intensive units are reconditioned for further use. As the negative effects of climate change continue to build momentum globally, efforts to reverse this trend must start locally by properly managing refrigerators and other white goods once they reach the end of their useful lives. As discussed in Chapter Two, the climate impact of a single EOL CFC refrigerator was presented, assuming the loss of 150 g of refrigerant and more than 125 g of blowing agent (average 25% immediate loss of 500 g) is the equivalent of releasing 2.165 metric tons of carbon dioxide. This calculation does not take into account the amount of carbon dioxide released as a result of operating the unit as 80% of emissions are related to the consumption of electricity and why it is so imperative that old energy inefficient refrigerators are not resold for continued use. As one participant of the survey remarked, removing one old refrigerator is the equivalent of taking two cars off the road for one year – in terms of carbon dioxide equivalency. If a difference is to be made in reversing the trend of global warming, a strategy for refrigerators and other large white goods in Manitoba must be developed.

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Appendix A: Refrigerator Management Survey

Introduction

1. Does your area currently have a system in place for the management of domestic appliances that contain an ozone depleting or global warming substance (such as a refrigerator or freezer, or any other appliance which may contain an ODS based insulating foam) at the end-of-life/post consumer stage?

If yes please proceed to question #2, if no please see question #36

Appliance Collection

2. Is there a standardized method in your area that ensures proper recovery of ODS/GHG and appliance recycling (i.e. adhere to one code of practice for areas with multiple appliance recyclers)?

3. What is the procedure when a resident calls and wants to dispose of an appliance, which contains a refrigerant (i.e. who should the resident call)?

4. What is or was the scope of your project (i.e. how many people or households does your program or management system target)?

Refurbishment

5. If an appliance destined for disposal is determined to still be in working condition, what happens to it and is refurbishment encouraged (or an option)?

6. What is the typical value of a refurbished appliance (i.e. the resale cost or the inherent worth of recoverable parts) and to what market are these appliances targeted?

7. Many appliance-recycling programs target secondary appliances only (by means of incentive). However, if a resident's primary refrigerator breaks down, are they still eligible to participate in the program (minus incentive perhaps)? If not, who would the resident contact?

Energy Efficiency

8. Are there any programs or incentives in your area that encourage the purchase of new energy efficient appliances, such as *Energy Star* certified models?

9. What types of incentives are given to residents as encouragement to recycle their appliance?

10. On a yearly average, typically how much energy is saved (kWh) from the removal of older primary and secondary appliances (chiefly refrigerators) from the market?

11. How is electricity generated in your area (to identify how much GHG has been prevented from being released—through the removal of these appliances)?

End-of-Life Fee's

12. If and when it is time for disposal...what is the typical cost levied against the resident at the time of disposal and what are these costs associated with (i.e. ODS extraction, pick-up, transportation, etc.)?

Transportation

13. How are appliances typically transported to the processing facility (i.e. resident drop-off or municipal/private contractor collection). Is the appliance picked up at the curb or in the house?

Decommissioning/Processing

14. Who is typically responsible for ensuring that refrigerant (CFC's, HCFC's, and HFC's) has been responsibly removed from the unit prior to recycling?

15. What is the most common method of refrigerant extraction (i.e. active recovery method or blue bottle)? Where is refrigerant typically recovered (i.e. indoors or out)?

16. Is there an ID system in place, such that an evacuated unit can easily be identified as refrigerant free (via a sticker or barcode system)?

17. What happens to the refrigerant once it has been removed (i.e. recycled, recharged, or destroyed)? If destroyed, to which facility is it sent?

18. Are there any laws in place that stipulate the mandatory recovery of ODS and GHG (i.e. CFC's 11 &12, HCFC 22, and HFC 134a)?

19. On average, how many ODS/GHG containing white goods are processed at your WDG/WTS on a _________ basis (i.e. daily, weekly, monthly, yearly)? How many non-ODS containing appliances (stoves, hot water tanks, etc.) do you receive in that same time period?

20. Are mercury switches from chest freezers and capacitors containing PCB's recovered from air-conditioners and microwaves prior to recycling?

21. Are refrigerant oils (i.e. mineral oils [with dissolved refrigerant]) recovered prior to recycling and if so, how is it collected and processed to remove the refrigerant? What applications would the recovered oils serve?

Recycling

22. What is the most common method of appliance recycling (shredding) in your area (i.e. car shredder or special refrigerator recycling technology)?

23. Is there an appliance recycling centre or scrap metal shredder in your area and if not how far is the closest one to your location?

Resource Recovery

24. What is done with the steel after the unit has been shredded? Typically, what products are made from the steel that is recovered from these domestic appliances?

25. Is it profitable to recycle appliances in your area and if so, which ones are the most profitable?

26. What is typically done with the other component parts prior to and post recycling (i.e. copper, aluminium, glass, and plastic)?

27. What is the current market price for these recoverable resources in your area?

    a. Aluminium:
    b. Copper:
    c. Steel:
    d. Glass:
    e. Plastic:

25. If at all possible, please list the total amount of resources recovered over the lifespan of your refrigerator management project.

    a. CFC's (11, 12, or both):
    b. HFC's:
    c. Refrigerant oil:
    d. Polyurethane foam:
    e. Aluminium:
    f. Copper:
    g. Glass:
    h. Plastic:
    i. Mercury switches (if applicable):

Polyurethane Foam Treatment

26. How are CFC's or GHG's that are housed in the insulating foams dealt with (i.e. removal of foam prior to shredding or shredded along with appliance releasing ODS into the atmosphere)?

27. What management system is in place to deal with foam after its removal from the appliance (i.e. incinerated, landfilled, etc.)?

28. What cost is typically associated with foam recovery (if applicable)?

Advanced Disposal Fee's

29. Does your area have any advanced disposal fees at the point of purchase for new appliances to help build the necessary infrastructure for an appliance-recycling program? If so, what has been the reaction from the consumers towards this ADF?

Manufacturer

30. What is the role of the manufacturer in your recycling program and what do you think it should be?

Conclusion

31. Is it advantageous to have a standardized recycling process (i.e. refrigerator decommissioning and recycling at one facility) rather than taking a multi-stakeholder approach to end-of-life management (i.e. different stakeholders responsible for various aspects of the end-of-life process)?

32. Overall…what is motivation for a good management system? Why are some programs better (or more efficient/effective) than others?

Non-Management Systems

33. Do you have any plans to institute an appliance-recycling program in your area?

34. Currently, what is preventing you from instituting this type of program (i.e. low volumes, etc.)?

35. What systems or resources would be needed for such a program (i.e. funding, equipment, personnel, or higher disposal rates/volumes)?

Final Thoughts

Is there any further information that you would like to provide about your appliance recycling program, which was not covered in a specific area of this survey?

Are there any further questions or final comments?

Thank you very much for your input.

Appendix B: Manitoba Metals Electronic Questionnaire

1. What is Manitoba Metals (MM) procedure for accepting refrigerators and ensuring the refrigerant has been removed properly (i.e. looking for decommissioning labels or cut lines)?

2. What happens if a person delivering a refrigerator to MM is found to still contain refrigerant in the compressor and cooling circuit (i.e. not accepted until decommissioned)?

3. On a weekly basis, how many fridges/freezers would MM receive and on average what is the price paid out per unit or ton.

4. From what areas does MM receive compacted white goods ("white logs")? Do these white logs consist exclusively of refrigerators or do they contain a mix of all white goods (i.e. fridges, washing machines, stoves, etc.)?

5. Is there any way to tell whether or not if compacted fridges have had the refrigerant removed properly (i.e. paper trail, etc – recognizing it may be impossible to tell once they have been crushed and cubed)?

6. What is MM policy towards mercury switches?

7. Whose responsibility is it for the safe removal of mercury switches from freezers and washing machines (i.e. certified technicians when removing Freon)?

8. Are appliances inspected for mercury switches prior to being recycled?

9. Does MM run a mercury switch collection program?

10. What is the procedure for identifying and treating PCB containing capacitors?

11. Is there any removal of refrigerant oils from the compressor prior to recycling?

12. Does MM have any type of abatement program to counteract the negative effects of a mercury or oil leak during recycling?

13. Is glass from refrigerators collected for recycling and is polyurethane foam and plastics still combined for onsite landfilling?

14. What is the current market value of the following resources: steel, copper, and aluminium?

15. Is it possible to provide some spec's on the type of shredder utilized by MM (i.e. make, model, horsepower, rpm's, etc.)

Appendix C: General Scrap Electronic Questionnaire

1. On a weekly basis, how many fridges/freezers would General Scrap (GS) receive and on average what is the price paid out per unit or tone.

2. What is GS policy towards mercury switches? Whose responsibility is it for the safe removal of mercury switches from freezers and washing machines (i.e. certified technicians when removing Freon)? Are appliances inspected for mercury switches prior to being recycled? Does GS run a mercury switch collection program?

3. What is the procedure for identifying and treating PCB containing capacitors?

4. Is there any removal of refrigerant oils from the compressor prior to recycling?

5. Does GS have any type of abatement program to counteract the negative effects of a mercury or oil leaks during recycling?

6. Is glass from refrigerators collected for recycling and is polyurethane foam and plastics still combined for recycling and/or landfilling (understanding the limited capacity of XPotential after the fire)?

7. What is the current market value of the following resources: steel, copper, and aluminum?

8. Is it possible to provide some spec's on the type of shredder utilized by GS (i.e. make, model, horsepower, rpm's, etc.)

Appendix D: M. Baker Electronic Questionnaire

Regulation

1. What is the cost associated with obtaining a waste management license?

2. Is there a different license for different types of waste that is being handled? Ie) your license provides specific measures for handling and treating waste refrigerators.

3. How often does the Environmental Agency inspect you for compliance? What are they looking for? How often do they audit your paperwork and record keeping?

4. Are there any recycling and reuse targets set under current legislation or stipulated within your waste management license?

Collection

5. Do municipal (local) collection centers need a waste management license to store waste refrigerators?

6. Is there any cost associated with residents dropping off their fridge at local collection centers?

7. How many local collection depots are within your collection zone?

8. In the local collection bids → how much money does the local government pay to have units collected? Flat fee or per unit?

9. How many regional collection teams does M Baker employ? How much of your collection is hired out to third parties? What is the procedure if an independent person drops units off at your facility?

10. What are the procedures for properly loading the collection trucks to ensure no refrigerant escapes?

11. Is it the local government's responsibility to ensure that WEEE is in a clean state (i.e. no organic matter left within fridges)? Do collection teams inspect units at collection point for cleanliness? Can they reject on site?

12. Who collects fridge's that have been illegally dumped (fly-tipping)? (Local govt.?)

Recycling

13. How may refrigerators must be processed to keep your business viable or profitable?

14. How many refrigerators do you process in a typical year?

15. What is the cost per unit to recycle a fridge?

16. Is there any way for your recycling machine to detect if a mercury switch has passed by disassembly and has been shredded within the machine?

17. What procedures are there if this occurs?

18. Do you know what is happening, in terms of recycling, with other types of equipment that contains ODS (ie. air-conditioners, water coolers, etc.)?

19. What is the name of your refrigerator recycling system? How much did it cost to purchase? How long would you expect to earn payback of initial purchase costs? What is the life span of this system?

20. Domestic units 60% - commercial units 40% of feedstock: how are the commercial units processed? Cut up, potentially release ODS in foam? Stated in Terms and Conditions of License that only accepted if capacity allows or under agreement with the contractor.

21. What is happening with pentane fridges? WML says have to recover hydrocarbons, is this necessary considering they are benign substances?

Reuse

22. There is no policy on reuse/refurbishment: why type of criteria is used to determine if a refrigerator can be reused? On any given day, how many units would typically be chosen for reuse?

23. After compressors are removed (as stipulated under your license), what happens with them? Are they being reused? Is it hard to find reuse value for an R-12 compressor?

Waste

24. Between the urethane foam and gasket fractions, how many tons of material is sent to the landfill each year?

25. What is the cost per tone to landfill in the UK?

26. Any idea what percentage of waste you are currently diverting?

27. Under waste acceptance procedures, what happens if refrigerators are rejected when they are received at the plant?

Hazardous Wastes/ODS

28. Under schedule 2 of Terms and Conditions, you are not allowed to accept loose or bagged urethane foam – where would this material come from? What would you instruct the client to do with it? Where could it be sent for destruction (at the client's expense)?

29. Table 4.1 of license: inspection and maintenance of containers (inspect refrigerant containers and compressors and a daily basis for leaks) – does this mean loose compressors (demanufactured) or compressors awaiting pre-treatment? Can assume some units will have leaks in the hermetic system while in storage.

30. What is your contingency plan in the event one of your main refrigeration container has/have a leak?

31. Are refrigerant and blowing agents being recovered in the same container? Is there mixing of refrigerant types (i.e. R-12, R-134a, etc.)? Does this add to disposal costs if "cross contaminated"?

32. In Appendix B of License – only identify CFC containing units and foams, what about HFC units and HCFC/HFC containing foams? Are all types classified as CFCs?

Extra

33. Currently, who is responsible for providing education and awareness to residents regarding recycling of refrigerators?

34. Explain in greater detail your contract with Ireland?

35. Expand on the bar code system: what type of information does it track?

36. What are procedures for sulfur dioxide or ammonia based refrigerators?

White Goods
Stewardship Focus Group
Meeting Agenda
April 27, 2007

1. Define designated material(s)

- Primary target: appliances containing a Class 1, 2, or 3 substance (ozone depleting or global warming substance, i.e. refrigerators, freezers, air-conditioners, dehumidifiers, heat pumps, etc.)
- Secondary: non-classified substance containing appliances (stoves, ranges, microwaves, water heaters, washers, driers, etc.)
- Incorporate white goods into the greater electronic product stewardship regulation (discuss reasons for or against) or have separate regulation?
- Is it more efficient to categorize all white goods together into one regulation (if separate from all other electronics) or only designate those, which pose the most significant post-consumer management problems and/or hazard to the environment?
- Estimating quantities of material flows (quantity and volume).
- Defining and identifying historical and orphaned products – as European systems have identified white goods as largest segment of historical/orphaned e-wastes.

2. Identify who a product steward is and what they are responsible for?

- Brand owner, First Importer, or Assembler.
- Role or duty of manufacturer (i.e. appliance manufacturer/assembler, foam manufacturer, component part manufacturers, etc.)?
- Formation of stewardship corporations and/or Industry Funding Organizations (IFOs) – define their role.

3. Define stewardship program plan:

- Identify all requirements: waste management plan (define components), appropriate management procedures, province wide collection system, payments for expenditures, collection of revenues, consumer awareness education, public consultations, etc.
- Optional requirements: research and development, training and education, pollution prevention activities, etc.
- Submission of program plan for approval: approvals, licensing, etc.

4. **Identify who an operator of an approved program plan is and what they are responsible for?**
   - Producer Responsibility Organizations (PROs) – define their responsibilities, etc.

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5. **Define components of a province wide stewardship system**
   - Collection logistics: who is responsible for collection and storage (municipal, retailer, or distributor collection depots)? How are units collected, for processing, from [municipal] collection points and who are they collected by?
   - Would it be advantageous to create waste management districts (i.e. split province into three or four zones)?

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6. **How is the stewardship program funded?**
   - Stewardship fees: who can asses a fee against a designated steward? How much are they, how are they paid, who collects them, how are fees reimbursed for expenditures?
   - Will stewardship fees be strictly internalized to stewards only or will they be shifted forward to consumers? Will the fee be visible or invisible to the consumer? Who has the authority to apply a fee (industry or minister)? Who would manage these fees?
   - What would be an appropriate fee to apply to the sale of white goods?
     - Fees range from $20-$50 CDN in Europe.
   - Are fees applied to both new and historical products on the market?
   - Do fees apply to historical products being resold on the market (i.e. refurbishment)?
     - Producers in Europe are allowed to place a visible fee on historical products on the market (for up to 10 years for appliances) but must solely finance recycling of new products.
     - White goods sector (Europe) supports visible fees because of significant historical wastes.

6.1 Fee Structures

- There are various options that can be used for the fee structure:
  1. Actual costs of recycling
  2. Projected costs of recycling
  3. Cross subsidization (i) - (i.e. in a multi-electronic program – funds from one category go towards funding recycling of another category).
  4. Cross subsidization (ii) – taking funds from an entirely unrelated product to fund appliance recycling.
  5. Weighted fees – consumers of historical products are charged a higher fee than consumers of new products.
  6. Variable fees – reflect differences in end-of-life management costs related to different products, brands, or sizes.

6.2 Free Riders

- How are free riders dealt with?

6.3 Feedback and Eco-design

- Does the stewardship framework provide any feedback or incentive to change product design or production processes to incorporate greener activities (i.e. less natural resource inputs, switching to hydrocarbon refrigerants, etc.).

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7. Performance measures and targets

- How are targets determined and set (collection, diversion, recycling)?
- How would collection and recovery targets be set, such that the quantity would be dependant on the estimate of the product lifespan?
- Are targets set for both historical/orphaned products, as well as, new products sold over the course of the program?
- How would the program accommodate the "one-time" surge of historical/orphaned products that would follow the implementation of the program – towards the setting of targets?
  - It has been suggested (from Ontario) that targets be set to drive diversion programs. In this case a recovery target of 60% was suggested.
  - Europe (WEEE Directive): for appliances – minimum 80% recovery rate by weight per appliance
- Institution of recycling and reuse targets?
  - Europe (WEEE Directive): for appliances – minimum 75% component, material and substance reuse and recycling by average weight per appliance.
- Restricting reuse – limited to component parts and not whole system reuse (due to high energy demand from older appliances)?

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8. Other

- Reporting
- Enforcement/penalties: what are they, how are they enforced?
  - Monitoring of ODS recovery in accordance with Reg 103/94?
- Establishing "best management practices" – BMP guidelines

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9. Roles and Responsibilities

- Provincial government
- Green Manitoba
- Industry: fund local collection systems, provide best available treatment and processing technologies, establish recycling infrastructure?
  - IFOs, PROs

- Local governments: provide collection services, storage space, public education, landfill bans, etc.?
- Retailers: consumer info
- Consumers: return products to collection facilities or make arrangements for collection, make informed choices when purchasing?
- Others: recyclers, refurbishers, certified technicians, ENGOs (MOPIA)?

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10. Questions/Notes

- Would best available technologies (BATs) be considered for use in this program?
- Since BATs are relatively expensive and require large volumes of materials to be viable – are they appropriate in this situation?
  - Europe (WEEE): producer responsible for providing best available treatment, recovery, and recycling technology.
  - Appliances containing ozone depleting/global warming gases must be treated appropriately in accordance with EC 2037/2000 on ODS.
- Create a link between regulations – with 103/94?
- Implementing harmonized approach with other jurisdictions (appliances designated waste in Ontario).
- What types of barriers exist for industry?
- What type of role does the public play in defining this program (through consultations)?

Agenda
End-of-Life Refrigerators:
Polyurethane Foams Discussion Group
May 7, 2007

Background

- Focus of project is on "end-of-life" responsibilities, related to the waste management of consumer products – in this case, household refrigerators.

- A typical refrigerator will contain 16 ounces of classified substance (CFC, HCFC, HFC) as blowing agent within its insulating foams.
- When recycled (shredded), 35 % of the blowing agent is immediately lost to the atmosphere and 65% offgases over time in landfill.
- 80-85% of all ODS currently in the atmosphere consists of CFC-11 – one of the most common blowing agents.

Discussion

- *Waste Management*

1. What type of role would the polyurethane foam manufacturers in Canada play (or be willing to play – physical and/or financial), towards establishing management or treatment programs for foams in discarded refrigerators?
2. What types of treatment methods or technology would your association suggest to curtail fugitive blowing agent emissions during the recycling process?
3. Are there currently any such initiatives in place within Canada for the recovery of blowing agents during recycling?
4. What would be some of the barriers your industry could be faced with from becoming involved in a [localized] refrigerator-recycling program?

- *Product Design*

1. What type of input does your association/industry have towards determining what types of blowing agents are used in the design and manufacture of refrigerators for sale in Canada?
2. What is the most effective blowing agent on the market today, in terms of insulating capabilities?
3. Why is there a mix of different blowing agent types being used within refrigerators on the market (i.e. R-22, R-134a, cyclopentane, etc.)?
4. A small percentage of refrigerators on the market utilize hydrocarbons as blowing agents, what types of incentives are there to use these environmentally friendly products? Why have they not been more widely accepted?